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VOLUME XIV
JANUARY-DECEMBER, 1924

WITH 31 PLATES AND 106 TEXT FIGURES

PUBLISHED FOR THE SOCIETY
SCIENCE PRESS COMPANY
LANCASTER, PA.

DATES OF PUBLICATION

January	number, Feb. 11	July	number, July 21
February	“ March 20	August	“ Aug. 20
March	“ April 12	Sept.	“ Oct. 6
April	“ May 6	October	“ Nov. 5
May	“ May 24	November	“ Dec. 2
June	“ June 27	December	“ Jan. 10, 1925

ERRATA

Page 7, line 8, read Georgia for “Goergia.”

Page 177, line 2 from bottom, period after *Medicago sativa* should be a comma.

Cover of September number, page numbers should be changed as follows: 406 to 408, 409 to 411, 422 to 424, 425 to 427, 428 to 430, 431 to 433.

Page 460, line 14 from bottom, read *Bacillus* instead of “Baccillus.”

Page 516, reference 1, “malaidés” should be *maladies*.

Page 516, reference 6, second line should be “*Biol. Centralbl.* 37: 373. 1917.”

Page 527, line 21, change “inoculation” to *inoculum*.

Page 530, line 4 from bottom, change “play a rôle” to, play no rôle.

Page 532, reference 2, n should be omitted from “Mended.”

Page 535, second paragraph, line 1, change “serniere” to *derniere*.

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PHYTOPATHOLOGY

VOLUME XIV

JANUARY, 1924

NUMBER 1

VARIETAL SUSCEPTIBILITY AMONG BEANS TO THE BACTERIAL BLIGHT

WALTER H. BURKHOLDER

Considerable progress has been made in New York State during the last few years, in the discovery of varieties and strains of beans (*Phaseolus vulgaris* L.) resistant to the various diseases to which this crop is subject, and in the developing of new strains of commercial varieties from such stock. Barrus (1) led the way by showing that the Wells' Red Kidney and the White Imperial were resistant to both the alpha and the beta strains of *Colletotrichum lindemuthianum* (Sacc. et Magn.) B. et C. From these two varieties, the writer (2), McRostie (8) and Reddick (9) have developed several other strains of commercial varieties of beans resistant to the anthracnose. A bush marrow introduced from Nova Scotia and reported upon recently by the writer (5) is being grown to a small extent in New York State and has proved more or less resistant to the anthracnose under field conditions. The appearance of a third strain of *C. lindemuthianum* designated as gamma (4) has seemingly complicated the breeding problem in respect to this disease. Varieties resistant to both alpha and beta strains are susceptible to the gamma strain. This third strain of the fungus, however, is of limited occurrence, and it is hoped at present that it will be of no economic importance.

Varieties of beans resistant to two other important diseases have been published upon in various articles. The Flat Marrow, a strain of beans resistant to *Fusarium martii phaseoli* Burkholder, the cause of a root-rot, was reported by the writer (3) and breeding experiments with this strain of beans were undertaken by McRostie (8). The most practical work, however, was the discovery at the Perry bean laboratory and the subsequent proving by Reddick and Stewart (10) that the Robust pea bean is immune to the mosaic disease. The growing of pea beans in New York had practically been discontinued due to this disease, but with the introduction of this bean, the acreage of the pea bean is now as large as formerly. From the Robust other varieties have been bred which are also mosaic resistant (8 and 9).

With the ever increasing prevalence of the bacterial blight caused by *Phytophthora phaseoli* (E. F. Smith) Committee S.A.B.,¹ strains of commercial varieties of beans resistant to this disease are greatly needed. Very few investigators have dealt with blight resistance among beans. Fulton (6) has reported some experiments and observations on varietal susceptibility, and recently Gloyer (7) has noted two distinct susceptible periods in the life of the bean plant; the seedling stage and that period from the formation of pods to maturity. With the beginning of the work reported in this article, it was noted from observations in the bean fields that none of the common varieties possess immunity. Single plant selection among these varieties likewise has shown no permanent resistance. Any variety of beans, then, having the character of blight resistance was desired for use as breeding stock. If this character behaved in a Mendelian fashion, as anthracnose resistance does, crosses with commercial varieties would no doubt yield a valuable type. Search for the character of blight resistance was begun in a systematic manner in 1919 and has been continued to the present time. No immune or highly resistant variety has been discovered, but certain degrees of susceptibility among the varieties have been noted which appear worthy of reporting. In this article an account is given of those experiments conducted in the field during the seasons of 1919, 1920, and 1921. The summers of 1922 and 1923 were not such to induce the rapid spread and development of the disease. This was also true of the summer of 1920, but the plots that year were inoculated a great many times so that infection was secured. Since infection was very light in all the fields that year, all varieties in the experimental plots showing a medium or light infection were considered to be rather susceptible, and were discarded from further tests. It was thought that they would approach a severe infection under favorable conditions.

In 1919 and 1920 the experimental tests were conducted at Perry, New York, and those in 1921 were at Ithaca, New York. The varieties of beans were planted in ten-foot rows which were about 28-30 inches

¹ Recently Miss Hedges (Science n.s. 55: 433-434. 1922) reported on a disease of beans similar to the bacterial blight, the causal organism of which differed in her description but slightly from *Phytophthora phaseoli*. Many anomalies are to be met with in the bacterial blight which have formerly been considered due to ecological factors. It is probable that some of these are due to physiological differences in the pathogenes, and that the species *P. phaseoli* constitutes a group just as certain species pathogenic to animals are known to do. Bacterial blight in this article refers to the bacterial disease of beans as it occurs in New York State and described elsewhere by the writer (Phytopath. 11: 61-69. 1921).

apart. After the plants were a little past the seedling stage, they were sprayed with a water suspension of the bacteria. The bacteria in some cases were obtained from pure cultures, and in other cases by chopping up blight-infected plants and soaking them in water. Three and four such inoculations were made until it was certain that sufficient inoculum for general infection was provided.

In table 1 are set forth the results obtained in 1919. Here three degrees of infection are recorded and are designated as *light*, *medium* and *severe*. The disease destroyed practically all the leaves of those varieties of beans placed in the group marked *infection severe*. Severe injury, too, was sustained by the pods. Those varieties in the group marked *infection light* showed considerably less injury although they did not possess sufficient resistance to make them valuable for breeding stock. The Robust pea bean is a good example of this group. Here the incubation period was approximately a week longer than in the former group. The spots on the leaves spread much more slowly and little injury was found on the stem and pods. Consequently unless infection was very early, serious damage did not occur to the plant. An intermediate group was formed for those varieties which were difficult to place in either of the above two groups. In table 2 are placed those varieties tested in 1920. During that season the disease was not severe on any of the varieties, as explained above, but it was considered that those showing the bacterial blight to any extent would be very susceptible in a blight-favorable year. In table 3 a similar grouping is made of those beans tested in 1921. Conditions were very favorable that year for the development and spread of the disease.

In looking over tables 1 and 3, one may observe that practically all those varieties showing a light infection in 1919 also remained in that class in 1921. This evidently demonstrates that those varieties do possess a certain amount of resistance. This resistance, too, is sufficiently great to recommend the use of these varieties in preference to similar ones in either of the other two groups. In general, however, the more resistant varieties are later in maturing, while those exhibiting severe infection are early. The correlation of the two characters, however, is not perfect.

A number of hybrids have been produced between the most resistant of the varieties in hope of increasing resistance. Very little progress has been made so far. The work is being continued, nevertheless, and further crosses are being made and tested.

TABLE 1—*Varieties of beans showing relative susceptibility to the bacterial blight during the season of 1919.*

INFECTION LIGHT	
Baldwin Wonder Wax	London Horticultural
California Pink	Manchurian Pea
California Wonder Pea Bean	Pearce's Improved Tree Bean
Early Golden Cluster Wax	Refugee 1000-1
Giant Stringless Valentine	Robust
Keeney's Stringless Green Pod	Scotia
Kenney's Rustless Golden Wax	Scotia
INFECTION MEDIUM	
Black Turtle Soup	Manchurian Cranberry
Bountiful	Marvel of Paris
Burlingame Medium	Maules Profusion Wax
China Eye	Michigan White Wax
Chutenashu	Michigan Wonder Pea Bean
Detroit Wax	Nova Scotia Marrow
Dutch Case Knife	Perfection St. Louis White
Diafuki	Pencil Pod Black Wax
Early Mohawk	Pinto
Extra Early Refugee Dwarf	Prolific German Black Wax
Extra Early Red Valentine	Prolific Tree Bean
Farquhar's Rustless Golden Wax	Red Marrow
Full Measure	Refugee Wax
Giant Stringless Valentine	Rust Proof Golden Wax Bush
Gray Marrow (South America)	Triumph of the Frumes
Harlequin	Vineless Marrow
Hodson Wax	Wells' Red Kidney
Japanese White Marrow	White Creaseback
Kentucky Wonder	White Wonderfield
Longfellow (Bush)	White Imperial
Mammoth Stringless Bush Bean	Yellow Six Weeks
INFECTION SEVERE	
Admiral Togo	Manchurian Kintoki
Black Valentine	Masterpiece Dwarf Bean
Boston Favorite	Mexican Red
Brown Swedish	Michigan White Wax
Challenge Dwarf Black Wax	Muroingen
Colossal Stringless Green Pod	Nagauzura
Currie's Rust Proof	Plentiful
Davis Wax	Old Mahogany
Flat Marrow	Ruby Horticultural
Golden Wax	Tennessee Green Pod
Improved Golden Wax	Scarlet Flageolet Wax
Isbell's Wonder Wax	Wardwell's Kidney Wax
Lazy Wife	

TABLE 2.—*Varieties of beans showing relative susceptibility to the bacterial blight during the season of 1920.*

INFECTION NONE	
Admiral Togo	Low's Champion
Burpee's Fordhook Favorite Bush	New Bountiful
Crackerjack Wax	New Dwarf Round Pod Intermediate Horticultural
Crackerjack Wax	Refugee 1000-1
Crystal White Wax	Refugee Wax
Flageolet Violet Wax	Round Yellow Six Weeks
German Black Wax	Round Yellow Six Weeks
Giant Stringless Green Pod	Snowflake Field
Golden Eye Wax	Webber Wax
Improved Yellow Eye	Worcester Mammoth
Isbell's Early Wonder Wax	
Isbell's Favorite	
INFECTION LIGHT	
Arlington Red Cranberry	Longfellow
Baldwin Wonder Wax	Low's Early Champion
Black Wax	Masterpiece
Bountiful	Missouri Wonder
Brown Swedish	Nancy Davis
Burpee's Stringless Green Pod	New Yellow Pod Bountiful
Brittle Dwarf Wax	Old-Fashioned Striped Sickle
Brittle Wax	Pheasant's Eye
California Rust Proof Wax	Prolific Black Wax
California Wonder Field Bean	Refugee 1000-1
Chinese Sword Bean	Refugee Wax
Cornfield Pole	Scotia
Crystal Wax	Snow Flake
Cutshort	Stringless Green Pod
Dwarf Hardy Wax	Stringless Kidney Wax
Early Six Weeks	Sure Crop
Early Yellow Six Weeks	Superior
Extra Early Refugees	Tennessee Green Pod
Extra Early Red Valentine	Texas Pole
Fairfield Wonder Wax	Unrival'd Dwarf Wax
Giant Stringless Green Pod	Vineless Marrow
Giant Stringless Green Pod	Warren
Golden Wax	Wells' Red Kidney
Improved Prolific Tree	White Kidney
Isbell's Golden Butter Wax	White Kidney
Jordan's Stringless Self Drier	White Seeded Kentucky Wonder
Keeney's Rustless Golden Wax	White Sickle
Kentucky Wonder Wax	White Wonder
Leonard's Webber Wax	Wonder of France
London Horticultural	Yard Long
INFECTION MEDIUM	
Flat Marrow	Perfection Pole Bean
French Asparagus	White Kidney

TABLE 3—*Varieties of beans showing relative susceptibility to the bacterial blight during the season of 1921.*

INFECTION LIGHT	
Baldwin Wonder Wax	London Horticultural
California Pink	Mont d'Or
Carter's Climbing French Bean	New Stringless Green Refugee
French Mohawk	Robust
Harlequin	Scotia
Italy's Favorite	Snowflake Field
Kenney's Rustless Golden Wax	Worcester
	Yard Long
INFECTION MEDIUM	
Arlington Red Cranberry	Lightning Early Valentine
Atwater White Kidney	New Bountiful
Burpees' Fordhook Favorite Bush	New Dwarf Intermediate Horticultural
California Rust Proof Wax	New Kidney Wax
Carter's July Climbing	Old-Fashioned Sickle
Carter's Stringless Holborn Wonder	Osborn's Early Forcing
Carter's Sunrise	Refugee 1000-1
Carter's White Model Dwarf French Bean	Refugee Wax
Condon's Earliest Market	Royal Dwarf White Kidney
Condon's "Sure Crop" Stringless	Rustless Golden Wax
Crystal White Wax	Southern Cornfield Bean
Early Golden Cluster Wax	Unrivalled Dwarf Wax
French Asparagus	Ventura Wonder
Giant Stringless Green Pod	White Mexican Tree
Golden-Eye Wax	Yosemite Mammoth Wax
Kenney's Stringless Green Pod	
INFECTION SEVERE	
Admiral Togo	Golden Eye Wax
Best of All	Green Seeded Flageolet
Blue Pod Medium	Isbell's Favorite
Brittle Wax	Isbell's Early Wonder Wax
Burpee's Saddleback Wax	McCaslon Pole
Canadian Glory	New Yellow Pod Bountiful
Carter's Longward	Round Yellow Six Weeks
Carter's Magpie	Southern Prolific Pole
Carter's Perpetual	Sure Crop Wax
Crackerjack Wax	Webber Wax
Currie's Rust Proof Wax	White Sickle
Eureka	Yard Long Pole
Flageolet Violet Wax	Yellow Eye

In 1919 some inoculation experiments were conducted on some species closely related to *P. vulgaris* which should be reported here. These

were carried along with the variety tests and in the same manner. All species tested during that season proved more or less susceptible. They are as follows: Henderson's Bush Lima [*Phaseolus lunatus* L.], the white Tepary [*P. acutifolius* Gray var. *latifolius* Freeman], the moth bean, [*P. aconitifolius* Jacq.], the Adzuki bean [*P. angularis* (Willd.) W. F. Wright], the Mung bean [*P. aureus* Roxb.], the California Black-eye cowpea [*Vigna sinensis* (L.) Endl.], the Ito San variety of the soy bean [*Soya max* Piper], and the Georgia Velvet bean [*Stizolobium deeringeanum* Bert.].

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LITERATURE CITED

- (1) BARRUS, M. F. An anthracnose-resistant red kidney bean. *Phytopath.* **5**: 303-307. 4 fig. 1915.
- (2) BURKHOLDER, W. H. The production of an anthracnose-resistant white marrow bean. *Phytopath.* **8**: 353-359. 1918.
- (3) ———. The dry root-rot of the bean. *Cornell Agric. Exp. Sta. Mem.* **26**: 1003-1033. Pl. 51-52, fig. 133-135. 1919.
Literature cited, p. 1032-1033.
- (4) ———. The gamma strain of *Colletotrichum lindemuthianum* (Sacc. et Magn.) B. et C. *Phytopath.* **13**: 316-323. 1923.
Literature cited, p. 323.
- (5) ———, and I. M. HAWLEY. Diseases, and insect and animal pests, of the field bean in New York. *Cornell Agric. Exp. Sta. Ext. Bul.* **58**: 1-38. 23 fig. 1923.
- (6) FULTON, H. R. Diseases of pepper and beans. *Louisiana Agric. Exp. Sta. Bul.* **101**. 21 p. 15 fig. 1908.
- (7) GLOYER, W. O. Bacterial blight of beans under field conditions. *Abstracts of Bact.* **6**: 40. 1922.
- (8) McROSTIE, G. P. Inheritance of disease resistance in the common bean. *Jour. Amer. Soc. Agron.* **13**: 15-32. 1921.
Literature cited, p. 32.
- (9) REDDICK, DONALD. A hybrid bean resistant to anthracnose and to mosaic. (Abstract) *Phytopath.* **12**: 47. 1922.
- (10) ———, and V. B. STEWART. Varieties of beans susceptible to mosaic. *Phytopath.* **8**: 530-534. 1918.

PLANT PATHOLOGY IN THE DUTCH EAST INDIES

CARL HARTLEY AND R. D. RANDS

The Dutch East Indies have been the scene of pioneer studies in tropical plant pathology.¹ These studies in most cases were initiated in response to some disease problem or crisis connected with the plantation industry in which many millions of European capital was early invested. Under the stimulus of acute losses from disease the managers of these great European estates in Java and Sumatra were not slow to want aid in preventing possible disaster. Most of them were growing exotic species, in vast pure stands which occupied the same soil year after year. The Government botanical institution at Buitenzorg, Java, a rendezvous of botanists from all countries of the world attracted by its famous gardens, was naturally called upon not only for direct help but also for guidance in the establishment of planters' experiment stations to study the various problems of the industry. As a result there now exists a large amount of published matter. With the exception of Japan, this probably exceeds in volume the literature from all other parts of Asia and the Pacific islands, though it is less familiar to American botanists than that from certain other parts of the Orient. The following account is based on three years' experience in plant pathological investigation in the islands of Java and Sumatra.

A short general statement about the Dutch East Indies may be helpful for the orientation of American readers. The Archipelago stretches out along the equator for a distance of about 3000 miles from Asia to Australia. It has about eight times the land area of our Philippines, with a population four times as great (47 million) and of much the same ethnic composition, though mainly Mohammedan. The distribution of this population is peculiar, in that three-fourths of it is crowded together on the island of Java, which is recently volcanic and very fertile but smaller than the state of New York. In contrast to the highly developed condition of Java, Borneo and New Guinea, each approximately the size of France, are not even completely explored. A great variety of agricultural conditions is met with, ranging from hot coastal plains with strictly tropical crops, to high, cool slopes and plateaux where northern plants are grown. Climate is in general very moist, but with

¹ The terms "plant pathology" and "plant disease" are used in this paper with the meanings which they commonly carry in the United States and therefore do not include abnormalities caused by insects and higher animals.

actually arid conditions in some parts during the dry season. In the regions with developed agriculture rice is the great native food crop, with maize, cassava (tapioca), sweet potatoes, peanuts, and a number of others less important. For export, sugar is the great crop, with rubber, tea, coffee, coconut products, tobacco, spices, and quinine, all grown on a considerable scale as plantation crops under European management. Despite the great importance of the primarily plantation crops in Java, their total area is not more than one tenth of that occupied by the native food crops.

Aside from some valuable mineral resources, plants and their products are the prime interest of both whites and natives in the islands, and the Europeans recognize well their need of help from the plant scientist. The excellent steamers connecting Java with Singapore are named in honor of the biologists Rumphius and Treub, and the latter boat is decorated with bronze tablets bearing lists of Treub's publications. Semi-technical abstracts of agricultural contributions appear prominently in the daily papers. A list of twenty-four series of technical publications containing botanical literature appearing in the Dutch East Indies is appended to this paper. The large number is due to the maintenance of separate series of *mededeelingen* (contributions) for each government laboratory and each of the planter's experiment stations.

DISEASES WHICH HAVE RECEIVED SPECIAL ATTENTION

Plant pathology has received its chief stimuli from diseases of four important plantation crops: the *Hemileia* leaf-rust of coffee, which became epidemic between 1880 and 1890; the *serch* and associated diseases of sugar cane, which also began to receive attention in the eighties; the *Bacterium solanacearum* wilt of tobacco which became prominent with the extension of this industry in north Sumatra; and the brown-bast of *Hevea* rubber, recognized as an independent disease only in the last decade. The early coffee epidemic resulted in disaster in Java, as elsewhere. Little investigative work of the modern type has been done on the disease itself in Java, the situation being met by the substitution of other crops or of inferior but more resistant coffee varieties. The resulting changes, however, were undoubtedly influential in bringing about the establishment of experiment stations, supported chiefly by the planters themselves, for the perennial plantation crops.

The sugar cane diseases stimulated more direct investigative attack, and were influential in causing the founding of the sugar experiment station, which became and has remained through a long period of years

the most important private agricultural investigative enterprise in the world. The book of Wakker and Went¹ on sugar cane diseases, abundantly illustrated in color, published in 1898, is an evidence of the early activity in sugar cane disease investigation. Intensive pathological investigations were not continued to the point of thoroughly distinguishing, and determining the causes of, several of the important cane diseases, but some further work is now being done. In the meantime, development of resistant varieties and such indirect methods as the growing of clean propagating stock in localities which remain free from disease have resulted in fairly satisfactory economic control of the recognized troubles.

In 1893, tobacco became the subject of intensive investigations, first in the form of planter-supported research administrated by the Buitenzorg Botanical Garden, and more recently in the privately established and controlled *Proefstations* at Medan in Sumatra, and Klaten and Djember in Java. This development was largely due to the losses suffered from *Phytophthora nicotianae* in the seed beds.² This disease still remains a principal subject of investigation at the station at Klaten, while the wilt due to *Bacterium solanacearum* has become the chief pathological problem in Sumatra. Extensive studies of the wilt organism have been published.³ Sanitation measures have been developed against both diseases, which appear to have economic value, but in neither case is the control as yet on a satisfactory basis. The work at Klaten has served as the basis for the publication of a recent manual on diseases and pests of tobacco, well illustrated in color.⁴

Hevea or Pará rubber, arising as an intensively handled major crop almost over night, and after the idea of scientific work on plantation crops had become well established, received from the first of its short history, more or less attention from the disease standpoint. After a time it was realized that dry tapping cuts, brown inner bark, and troublesome "burr" growths were all common manifestations of the brown-bast disease, and were causing so much loss as to endanger the

¹ Wakker, J. H., and F. A. F. C. Went. *De Ziekten van het suikerriet op Java*. Deel I, Ziekten, die niet door dieren veroorzaakt worden. 217 p., 25 pl. (16 colored). Leiden, 1898.

² Encyclopedie van Nederlandsch Oost-Indië. 4: 98-99. 1921.

³ Honing, J. A. Numerous papers on *Bacterium solanacearum*, mostly in the *Mededeelingen* of the Delproefstation (Medan, Sumatra) 1910-1913 incl.

⁴ Jensen, Hj. *Ziekten van de Tabak in de Vorstenlanden*. 171 p., 86 fig., 58 pl. (25 in color). Leiden, 1921. (Also issued as Meded. 40, Proefsta. voor Voorstenlandsche Tabak.)

future of the industry. A definite investigative drive was at length made against the disease, the Dutch authorities cooperating with the planters' organizations, and the technical workers representing the interested parties throughout Malaysia keeping in communication with one another. Results were prompt and quite satisfactory. A complete change in tapping methods and surgical treatment of trees already give promise of reducing the loss from this trouble to a negligible minimum. The disease is believed to be non-parasitic, a direct result of too frequent tapping, and excessive latex removal.¹

In addition there may be noted a number of problems which have aroused less interest. Cacao canker and pod rot (*Phytophthora faberi* Maub.) have received intermittent attention for 20 years; both crop and disease have now so dwindled in importance that further study in Java seems unwarranted. Pepper, a native crop of rather large export value, has disappeared from certain sections where it was formerly important, largely as the result of a trouble which despite some investigative effort² still remains obscure. The peculiar "blood disease" of bananas in Celebes, a vascular bacterial trouble, has proved very serious.³ In the course of its investigation a general search for vascular banana diseases has been made, and an entirely different bacterial wilt,⁴ usually chronic instead of acute, has been found nearly universal both in Celebes and Java. In this chronic disease there is an interesting secondary flora, consisting largely of *Fusaria* and other bacteria, some components of which may aid in producing the diseased condition. This disease seems to offer an exceptional opportunity for investigating the relative importance of primary and secondary organisms. Only etiological work has been done on these banana diseases, and unfortunately nothing more is now in prospect.

¹ Rands, R. D. Brown bast disease of plantation rubber, its cause and prevention. Dept. Landb., Nijv. en Handel (Dutch East Indies). Inst. Plantenziek. Meded. **47**. 57 p. 5 pl. 1921

² For a summary of the literature on the subject see, Gaumann, E. A. Enkele opmerkingen omtrent de Lampongsche peperziekte. *Teysmannia* **33**: 289-293. 2 text figs. 1922

³ Gaumann, E. Onderzoekingen over de bloed ziekte der bananen op Celebes I. Dept. Landb., Nijv. en Handel (Dutch East Indies), Inst. Plantenziek. Meded. **50**. 49 p., 6 pl. 1921

⁴ Gaumann, E. Over een bacterieele vaathundelziekte der bananen in Nederlandsch-Indie. Dept. Landb., Nijv. en Handel (Dutch East Indies), Inst. Plantenziek. Meded. **48**. 135 p., 18 fig., 8 pl. (1 in color) 1921. Comparisons of this trouble with the "Panama disease" of the West Indies are discussed by Blandes, E. W. Onderzoek op grooten afstand betreffende de verwelkings-ziekte der bananen. *Teysmannia* **33**: 294-297. 1922. (See also postscript by E. A. Gaumann in reply to this, pp. 297-300).

Individual pieces of work, mostly recent, have been done on the *Sclerospora* mildew of corn,¹ and on diseases of quinine,² of peanut,³ and of potato.⁴ A curious *Phytophthora* stripe canker of cinnamon, sometimes several meters in length, but never more than a few centimeters in width, with a definitely daily-zonate length extension of almost invariably 1 cm. per day, which could not be correlated with physical factors, has been investigated in Sumatra.⁵

A disease conspicuous by its practical absence in the Malay Peninsula⁶ as well as in the Dutch possessions is the epidemic bud rot of coconut, and the various other evidences of *Phytophthora* attack on coconut noted in British India. This is the more interesting, as bud rot has made serious trouble on both sides of the Dutch Indies, in the Philippines as well as in India. Another disease less serious than in the Philippines is the *Sclerospora* maize disease. Recent mycological work has indicated that the *Sclerospora* and the common *Phytophthoras* of the palmivora-faberi type of the Philippines are quite different from those of Java.⁷ The *Phytophthoras* at least differ in parasitic ability as well as in morphological characters, and a difference in parasites may therefore explain the differences in disease prevalence in both these cases.

Forest pathology has been chiefly limited to some recent publications of the forestry experiment station at Buitenzorg on non-parasitic troubles in the intensively handled teak forests. Of the pathology of the tre-

¹ Palm, B. J. Onderzoekingen over de omgelyer van de maas. Dept. Landb., Nijv., en Handel (Dutch East Indies) Lab. Plantenziekt, Meded. **32**: 77 p., 7 pl. 1918. (With English summary.)

² Rant, A. Five recent papers (see bibliography by Van Overeem -de Haas, Le.)

³ (a) Palm, B. T. Aanteekening over slijmziekte in *Arachis hypogaea* (Katjang tanah). Dept. van Landb., Nijv., en Handel (Dutch East Indies), Inst. Plantenziekt. Meded. **5**: 41 p., 2 fig. 1922. (With English summary.)

(b) Groenewege, J. Landbouwkundige onderzoekingen over de slijmziekte. Dept. Landb., Nijv., en Handel (Dutch East Indies), Meded. **12**: 79 p., 16 pl. 1922.

(c) Hartley, Carl and Schwarz, M. B. Papers soon to be published.

⁴ Paravent, E. Die Kartoffelkrankheiten in Niederländisch—Ost Indien. Centralbl. Bakt. Abt. 2, **58**: 212-220. Mr. 1923.

⁵ Rands, R. D. Streepkanker van kaneel, veroorzaakt door *Phytophthora cinnamomi* n. sp. Dept. Landb., Nijv., en Handel (Dutch East Indies), Inst. Plantenziekt. Meded. **54**: 54 p., 6 pl. (1 in color) 1922. (With English summary.)

⁶ Sharples, A. and J. Lambourne. Observations in Malaya on bud-rot in coconuts. Ann. Bot. **36**: 55-70. Pl. I-VII. 1922.

⁷ Weston, W. H. Philippine downy mildew of maize. Jour. Agr. Research **19**: 97-122. 1920.

Recent unpublished work by the senior writer on the variability in *Phytophthora* of the *P. faberi* type.

mendous variety of tree species in the higher altitude "wildhout" forests, practically nothing is known, beyond the enumeration of 40 mistletoe species¹ and the occurrence and mycological data given by Raciborski² and others on some of the parasitic fungi.

A large number of purely mycological papers scattered through European and East Indian periodicals have been published. Many of the descriptions in these, unfortunately, were based only on the study of dried specimens brought back to Europe by travellers some of whom were not even botanists, so that the status of a number of genera and species is uncertain. A valuable survey and compilation of the existing literature has been made by van Overeem,³ recently appointed mycologist to the Buitenzorg Botanical Garden. In addition he gives a list of all the fungi he has been able to find reported to date for the Netherlands Indies. Of special interest to the pathologist are the papers on parasitic species in which notes on severity and distribution accompany the descriptions. The most important of these involving a series of three papers is by Raciborski, who describes a large number of interesting parasites on a variety of host plants. Despite the seemingly extensive mycological literature, comparatively little is known of the rich fungus flora of the islands. Intensive study along this line will be seriously handicapped by the local deficiency of comparative material, since most of the collections and exsiccati of new genera and species are in private herbaria scattered through Europe.

In general, plant diseases are abundant in Java, especially on recently introduced crops and in case of many vegetables where the seed is imported every year. Here one may observe not only the common diseases with which he is familiar in colder climes, but often new ones indigenous to the tropics which have spread over from native host plants. An instance of this is the glume spot of wheat caused by *Nigrospora javanica* Zimm.,⁴ a parasite apparently reported only from Java, which prior to the introduction of wheat into the island had been found only on a species of *Panicum*, and on rice and maize. However, one coming from the

¹ Koorders, S. H. *Exkursionsflora von Java* 2: 155-167. Jena, 1912.

² Raciborski, M. Sixteen papers on the fungi of Java, 1897-1909. For citations see p. 140-141, and especially citation No. 190 of van Overeem's bibliography, l. c.

³ Overeem-de Haas, C. et D. van. *Verzeichnis der in Niederländisch Ost-Indien bis dem Jahre 1920 gefundenen Myxomycetes, Fungi, und Lichenes*. Bull. Jard. Bot. Buitenzorg Ser. III, 4: 1-146. 1922.

⁴ Palm, B. J. *Eenige ziekten waargenomen aan de tarwe op Java*. Dept. Landb., Nijv., en Handel (Dutch East Indies), Inst. Plantenziek. Meded. 34: 17-18. Fig. 11, 12. 1918.

Temperate Zone is a little surprised at not finding still more numerous and conspicuous diseases in so warm and moist a country. Raciborski, perhaps the keenest observer who has looked for parasites in Java, remarks that at first he was unable to see them because the novelty of the vegetation in general distracted his attention. However, even after that wore off, he did not think that he found as many things (referring to parasites of the natural vegetation) as he would in an equal length of time in Europe. This indicates the difficulty of locating indigenous species rather than an actual paucity of number. For example, one of the writers searched nearly two years before finding Raciborski's *Phytophthora colocasiae*, whereas under the variable monsoon climate of semi-tropical Bengal, Butler and Kulkarni report it very common and destructive. So rare are many of the new genera and species described by Raciborski and others in Java that the occasional finding of them is nothing short of a rediscovery. In a country with such great uniformity of climate and multiplicity of host species, the proportion of "rare" fungi is probably greater than in temperate regions where there is constant interference in the natural adjustment and establishment of equilibrium between parasite and host. There are doubtless also contributing factors which aid the host in offsetting the apparent advantage to the fungus of tropical temperature and moisture. The temperature ($\pm 30^{\circ}$ C.) of Java is almost constantly above the optimum for a number of parasites, and its equability probably also assists the host plant in maintaining its equilibrium and resistance toward some others. The Wisconsin tests have emphasized the dependence of certain diseases on the occurrence of temperatures considerably above or below the mean.

Rainfall in most of Java ranges from 80-160 inches per year, decidedly more than the 30 inches of our Missouri Valley, the 45 inches of the Atlantic seaboard, or the rainfall figures for Europe. In much of West Java, the total precipitation exceeds the total evaporation. However, fog is rare, and rain when it comes is commonly heavy,¹ perhaps washing spores off of surfaces that might otherwise become infected. At low and moderate elevations, at which most crops are grown, nearly every morning in the year is clear and drying, at least for a few hours, even in the wettest districts.

¹ Taking the year, the weather records of which happen to come first to hand (1918), it is found that at Buitenzorg, which is situated at an elevation of 900 ft., there were 73 days on which rain reached cloudburst intensity, i. e., a rate of 1 mm. per minute for at least a 5-minute period. In a number of these cases the rain exceeded 2 mm. per minute for a period of 5 or more minutes.

AGENCIES ENGAGED IN PATHOLOGICAL INVESTIGATIONS

Up to the last half dozen years most of the pathological investigation had been done by the planters' stations previously referred to. As a result its publication has been scattered through semi-technical periodicals and numerous independent series of reports and *mededeelingen* (contributions), mainly in the Dutch language and many of them little known outside of Java. This accounts in considerable part for the lack of acquaintance of outsiders with what has been done. These stations have constituted a unique feature in the agricultural organization of the

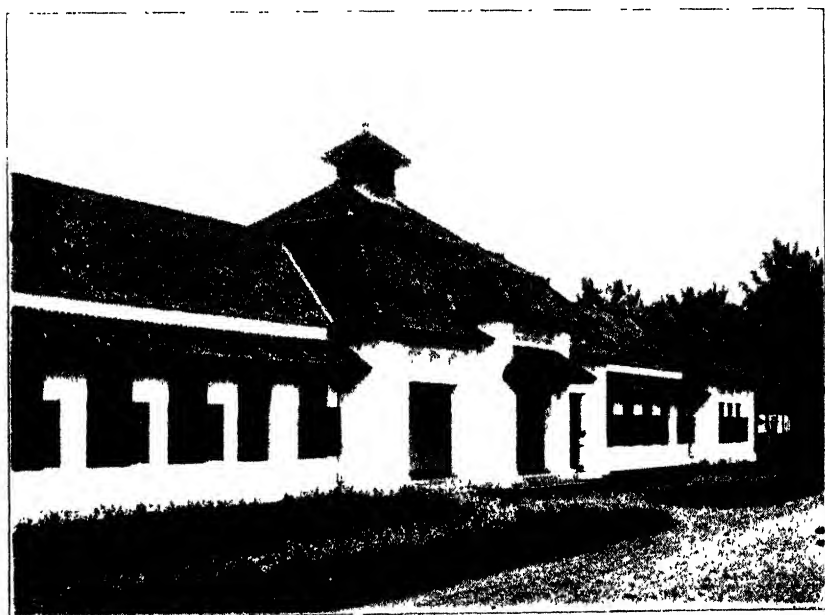


FIG. 1.--The Government's Institute for Plant Diseases, Buitenzorg, Java. Approximately half of the building is here shown.

islands. Their development is largely due to the commendable policy of the Government in confining its own activities largely to the improvement of native agriculture and at the same time encouraging the European agricultural interests to handle their own specialized problems. The planters have now learned by experience that it pays them to finance investigative work on their own crops. There are at present eight independent private or mainly private planters' stations in Java

and two in Sumatra. The names of these stations, the crops studied, and the territory represented, are as follows:

Algemeen Proefstation der A.V.R.O.S., Medan, Sumatra. Rubber, oil palm, coffee, and all other plantation crops except tobacco in north-east Sumatra. Tea problems are studied in cooperation with the station at Buitenzorg. The building belonging to this station is shown in fig. 3.

Algemeen Proefstation voor de Theecultuur, Buitenzorg, Java. Tea; territory covered—entire Dutch East Indies.

Besoekisch Proefstation, Djember, Java. Tobacco, rubber, coffee, and other "hill cultures," in extreme eastern end of Java.



FIG. 2.—Present staff of the Institute for Plant Diseases, Buitenzorg, Java. The Director, Dr. C. J. J. van Hall, is at the center, seated, and Dr. Marie B. Schwarz, the pathologist, next to him. The other investigators are entomologists.

Centraal Rubberstation, (*Vereeniging Centraal Rubberstation*). Buitenzorg, Java. Studies primarily the chemistry and physical properties of the product in cooperation with local stations; scope—Dutch East Indies.

Deli Proefstation, Medan, Sumatra. Tobacco on east coast of Sumatra.

Proefstation v.d. Java Suikerindustrie, Pasoeroean, East Java, and branches at Semarang, and Cheribon, central Java. Sugar.

Proefstation Malang, Malang, Java. Rubber and coffee in East Java.

Proefstation Midden Java, Salatiga, Java. Rubber, coffee, cacao, nutmeg, and coca (cocaine plant), in central Java.

Proefstation voor Vorstenlandsche Tabak, Klaten, Java. Tobacco in central Java.

Proefstation West Java, Buitenzorg, Java. Rubber in western Java. Now directed by the head of the tea station, with which it is likely to be combined.



FIG. 3.—Experiment Station of the AVROS (*Algemeen Vereenigend Rubber planters Oostkust van Sumatra*), Medan, Sumatra. This is one of ten investigative and extension centers supported by the different planters' associations in Java and Sumatra.

In addition to the above a number of the larger plantation companies maintain investigative departments of their own, in which one or more botanists are employed, as the U. S. Rubber Co., Kisaran, Asahan, Sumatra, and the *Rubbercultuur Maatschappij Amsterdam*, Galang, Sumatra. All of the above stations are supported by strongly organized planters' associations by an annual tax, based on production or area under cultivation by the subscribing members. In the case of sugar,

for example, this amounted in 1922 to more than \$0.90 per acre, giving the station an income of nearly \$500,000. The other stations have smaller incomes, totalling approximately \$400,000. Some of the stations are still aided by very small annual subsidies by the government and also receive contributions from business firms and individuals. While considerable research work is done at these stations, it is frequently insufficient as a basis for the extension work demanded by the planters. The average planter enjoys the proprietary feeling it gives him to have a scientifically trained man at his beck and call and he is frequently unhappy unless a visit is made to his plantation every so often, even though he has no immediate problem to solve. This takes time and tends to replace basic research by a great deal of desultory local experimentation. This situation, however, is realized by the people concerned and steps are being taken to differentiate more clearly between research and extension activities. Despite these difficulties, a large part of the remarkable progress of the plantation industry and the consequent rapid development of the colony in other respects is to be credited to the planters' stations.

The tobacco and sugar stations are the only ones with resources enabling them to attempt continuous research in pathology except incidentally to their extension activities. On account of the financial depression following the war, serious investigation of pathological problems will probably in the future, at least for some time, depend mainly on the government.

Government pathological work, together with the other plant protection lines, agricultural entomology, and the control of field rodents, is now theoretically limited to the *Instituut voor Plantenziekten* (Institute for Plant Diseases), established at Buitenzorg, Java, the seat of most of the government's agricultural investigations. Other subdivisions of the Department of Agriculture, as the quinine station, the general experiment station, the forestry experiment station, and the government rubber plantations, also engage more or less in pathological work. The *Instituut* (formerly known as *Laboratorium* and *Afdeling*) was established ten years ago, but until 1919 counted only one botanist on its staff. Its botanical complement was then raised to two permanent positions, and two additional botanists have been employed for temporary periods.

FACILITIES FOR INVESTIGATIVE WORK

At Buitenzorg facilities for pathological work are on the whole very good. The *Instituut voor Plantenziekten* is in most respects well

equipped technically, and is located in a commodious new building (Fig. 1) in the midst of the 60-acre *Cultuurtuin* (economic garden devoted to plantation crops) and the selection garden of about equal area, where the investigative work on native crops is centered. The well known taxonomic garden, the large herbarium, and the large library of the Department of Agriculture are useful adjuncts. The herbarium, however, has been sadly deficient in fungi and the library shows gaps in numerous important places, particularly serious for the pathologist being the lack of bulletins of our state experiment stations. This latter deficiency seems to have been in considerable part due to the failure of many of our stations to maintain proper foreign mailing lists.

Assistance of low grade is available in abundance in the form of native "boys" able to read and write Malay and handle very elementary arithmetic. Their pay ranges from \$5 to \$20 per month. They can be used to advantage for making culture media, transferring cultures, running a microtome, and in field experiments, though most of them require very careful control. The Institute has a native photographer, a technologist, and native artists remarkably good with either ink or water color.

The planters' experiment stations vary considerably in the matter of equipment. At least the sugar station in East Java and the "Avros" station in northeast Sumatra seem to be particularly well provided with library facilities. The library of the Department of Agriculture at Buitenzorg maintains loan service for the entire Archipelago.

Especially in Sumatra and West Java the difference between the wet and dry seasons is so slight that one has to the full the tropical advantage of being able to run field experiments at any time of year, making possible much more rapid progress in some types of work than can be had in the Temperate Zone.

NON-INVESTIGATIVE ACTIVITIES

The only educational work in plant pathology is that given as a part of a 2-year course in botany in the Intermediate Agricultural School at Buitenzorg, a training school primarily for the native agricultural extension service. There is nothing corresponding to the College of Agriculture in the Philippines or the special training given to the natives who are detailed to the research laboratories at Pusa. The consequent lack of trained research assistants in the Dutch Indies is handicapping pathological investigation.

Extension work on the diseases of plantation crops is done very ef-

fectively by the planters' stations and the semi-technical journals. The government's Agricultural Information Service furnishes an avenue for the extension of knowledge of the methods of combating diseases of native crops. The government has done a great deal in furthering native agriculture.

A rough plant disease survey has been maintained for a number of years by monthly reports from the agricultural extension officials in Java and certain other well settled parts of the Archipelago, and by the annual disease reports from the planter's stations. These come to the Director of the Institute for Plant Diseases, who combines them with his own notes and the data on insect pests in an annual publication in the *Mededeeling* series of the Institute.

There is no nursery business of importance, and regulatory activities are practically limited to guarding against the introduction of foreign pests. This is controlled by the Institute under a new law. Propagating stock must be certified as pest-free by inspectors in the country of origin, and is admitted only through the port of Batavia, where it is again inspected, and sometimes brought to Buitenzorg for fumigation. Seed of about 30 genera of European vegetables and annual ornamentals are excepted from the operation of the law, as are all seed intended for consumption. Fruits for consumption are admitted, subject to inspection, at a few principal seaports. Limitation of propagating stock to a single port of entry does not work serious hardship for the reason that there is no importing business of importance in this line.

A single domestic quarantine, prohibiting the movement of bananas (fruit as well as plants) from Celebes to other islands or to any other part of the world, has been recently put into operation. This is due to the presence there of the "blood disease."

STATUS OF PLANT PATHOLOGY

For the Archipelago as a whole, plant pathology is still in the reconnaissance stage. The more conspicuous diseases are of course known, but experience in both Europe and America has shown that these are not necessarily the most important. There has been an unfortunate lack of continuity in disease investigation, a characteristic of most tropical studies, so that results of economic value have not generally been obtained. One of the government agriculturists at Buitenzorg has recently published a rather sharp attack¹ on pathologists in general for going

¹ Groenewege, J. Landbouwkundige onderzoekingen over de slijmziekte. Dept. Landb., Nijv., en Handel (Dutch East Indies), Meded. **12**. 79 p. 16 pl. 1922.

only into the etiological aspects and thereby missing the additional opportunities for economic results that might come through further study of the diseases. There is a general impression that investigation of insect troubles is much more important than work on all other types of trouble combined. The Institute for Plant Diseases is now spending four times as much money on entomological projects as on pathological ones. The relatively low present standing of plant pathology seems to be in part due to the lack of continuity above referred to, and in part to the fact that pathological investigations have too often in the past been made by general botanists rather than by trained pathologists. It is believed that careful persistent work on some of the numerous little investigated crop plants would result in better appreciation of the economic value of pathological research.

A number of important problems or groups of problems are awaiting investigation, especially in connection with "native agriculture." The existence of serious diseases of the banana and of the pepper plant has already been mentioned. No control measures for these are known, and in the case of the pepper die-back the cause or causes have not been determined. Not even a thorough survey has been made of the diseases of such important food crops as rice, maize, cassava, and sweet potatoes, each of which in Java (with the exception of sweet potato) occupies an area from one to six times that of all plantation crops put together.

Although Java alone produces about 200 million bushels of rice annually there must be purchased in uncertain foreign markets approximately 20 million bushels additional to feed the native population. The local production of more rice is therefore one of the great problems of the East Indian Government. It is a well known fact that in a number of important districts the average yield per acre has been falling off in recent years and that crop failures are frequent. Some of these failures are traceable to the stem borer, drought, floods, etc., but those not due to such obvious causes are attributed to such a variety of agencies as to show on the face of the reports that the etiology is uncertain. All sorts of contradictory popular explanations of the failures are encountered: soil barrenness, too early planting, too late planting, untimely rains, improper cultivation, use of unsuitable varieties of rice, etc. A sucking insect which attacks the grain in the milk stage, and at least in West Java and Sumatra one or more fungi attacking leaves and seed, do considerable damage, but are not believed to be responsible for the entire failures noted. The hypothesis that nematodes are important as causes of rice disease in Java is not now generally credited. The condition known as *omo mentek*, also commonly referred to as root rot

by agronomists familiar with it, has been under investigation for years from the soil standpoint. The data obtained on the relation between soil aeration, atmospheric moisture, and the development of disease symptoms in rice are interesting and important; but the general problem of the rice failures seems to be too complicated to be explained on any simple basis. The likelihood of the presence of fungus or bacterial parasites able to attack the roots or the stems of the rice under favorable environmental conditions has never been investigated in the East Indies by modern methods. A thorough study of rice diseases in general, continued through a period of years by experienced pathologists cooperating with soils or physiological investigators, should prove more economical than the present very costly subterfuge of attempting to meet the increasing shortage by extension of the area under cultivation.

There has been some tendency for investigators to select problems without reference to the economic importance of the crops involved. This tendency has been by no means confined to the tropics. In the early work in most countries the diseases for investigation have been chosen because they were conspicuous, or because people of standing complained about them. This was in large part logical. The conspicuous disease is relatively easy to get data on. The disease that is complained of in the tropics is usually a plantation problem; the planter will help to get appropriations for investigation, will cooperate in the investigative work, and will ordinarily utilize any economic results obtained, while the native cultivator cannot be counted on to help in the work or to change his time-worn methods and prejudices readily enough to profit by the findings. But some of the plantation crops are not important. Work of maximum economic importance cannot be done on the less important crops. It is true that an unimportant crop sometimes has a disease especially favorable for the investigation of fundamental pathological questions, but fundamental research can in nearly all cases be more efficiently carried on in the temperate than in the torrid zone.

SUMMARY

1. The Dutch East Indies have in the past taken a leading part in tropical plant disease investigation. The more important diseases so far studied are noted. The clear mornings, equable temperature and lack of fog are considered factors in keeping down the seriousness of certain types of diseases.

2. Plant pathology does not have the standing with agriculturists that it should have, owing mainly to a tendency on the part of investigators

to leave a problem before they have worked long enough on it to get reliable results on the control aspects.

3. Much of the past pathological work has been done by the botanists of the various privately supported planters' stations. The number of investigators working mainly or entirely on plant diseases is now smaller than formerly.

4. Plant quarantine regulations are briefly described.

SERIAL BOTANICAL PUBLICATIONS OF THE DUTCH EAST INDIES

A. Journals

Arch. Suikerindustrie (contains all Meded. v/h. Proefsta. Suikerindus -sugar).
Arch. Rubbercult. (Contains all research work from "Centraal Rubber-station," "Proefstation West Java," and "Rubber Serie" of the "Algemeen Proefsta. A.V.R.O.S.")

Ann. Jard. Bot. Buitenzorg (systematic botany).

Bull. Jard. Bot. Buitenzorg (mainly systematic)

De Tropische Natuur (organ of the Netherl.-Indies Natural History Soc.)

De Thee (contains semi-popular articles, and reviews of technical articles on tea which appear in Meded. Proefsta. Thee.)

Tectona (official organ of East Indian forestry association)

Treubia (general biological journal).

Icones Bogoriensis (systematic—mainly descriptions of new species and genera).

B. Serial Mededeelingen (Contributions) from Dept. Landb., Nijf., en Handel. (Dept. Agr., Industry, and Trade, Buitenzorg Java.)

Meded. Algemeen Proefsta. v/d Landbouw (agronomy and soil science).

Meded. Afdeeling Zaadteelt (selection and improvement of native crops).

Korte Berichten van het Selectie en Zaadtuin (brief reports on plant selection).

Meded. Instituut voor Plantenziekten (plant diseases and insect pests).

Meded. Landbouw voor lichtingsdienst (agricultural extension service).

Meded. Knaa Proefstation (studies on gumme industry)

Meded. Proefstation voor Boshwezen (technical forestry articles)

C. Serial "Contributions" from planters' experiment stations.

Meded. Besoekisch Proefstation (tobacco, rubber, and coffee).

Bull. Deli Proefstation (tobacco).

Vlugschrift Deli Proefstation (tobacco circulars).

Meded. Proefstation van den A.V.R.O.S. (Algemeen Serie) (oil palm, etc.)

Meded. Proefstation Malang (rubber and coffee).

Meded. Proefstation voor Vorstenlandsche Tabak (tobacco).

Meded. Proefstation Midden Java (rubber, coffee, cacao, nutmeg, coca, etc.).

Meded. Proefstation voor Thee (tea).

Publicaties v/h. Nederlandsch Indisch Landbouw Syndicaat (Netherlands Indies Agricultural Syndicate, a union of planters' associations, publishes official minutes of planters' meetings and papers read).

There have just been received two interesting pamphlets on botanical and (agricultural) chemical investigations, parts of "The History and Present State of Scientific Research in the Dutch East Indies", published by the Koninklijke Akademie van Wetenschappen, Amsterdam, 1923.

ABSTRACTS OF PAPERS PRESENTED AT THE FIFTEENTH
ANNUAL MEETING OF THE AMERICAN PHYTOPATHO-
LOGICAL SOCIETY, CINCINNATI, OHIO, DECEMBER 27,
1923 TO JANUARY 1, 1924.

Progress report on cabbage yellows investigations in Kansas. E. A. STOKDYK.

Three seasons' experiments in the greenhouse and field show that Wisconsin "All Seasons" and Wisconsin "Brunswick" are resistant to yellows if the seed is sown in a hotbed and the plants transplanted to the field. These varieties are susceptible in some cases if the seed is sown directly in the field. A selection of Copenhagen obtained from Iowa is giving considerable promise for Kansas conditions. Three varieties imported from Scotland have desirable qualities and some resistance.

Studies conducted to determine whether or not the causal organism is ever carried in or on the seed, have shown no direct evidence that either was the case. Several *Fusaria* have been isolated but they failed to produce yellows in cabbage or give the characteristic reaction of *F. conglutinans* on cooked rice.

F. conglutinans callistephi Beach, which causes Aster Wilt, failed to cause yellows in cabbage.

A progress report on black-rot investigations, with special reference to cauliflower on Long Island. F. E. CLAYTON.

Bacterium campestre overwinters rather frequently in the stems of surviving plants of cabbage and brussels sprouts. No cauliflower plants live over winter. Repeated attempts to secure infection in the spring with soil and plant refuse from previously infested cauliflower fields have failed. Cauliflower plants grown to maturity in cheesecloth cages have remained free from disease, while others just outside were badly attacked. Plants in the cages made an extremely luxuriant growth and were proven by inoculation to be more susceptible to the disease than those outside. Protecting plants from contact with cultivation tools, horses and man, by fencing, and from rain by a glass roof reduced the amount of disease. Negative results from attempts to spread the disease with worms, but observations point to other insects as major disseminators.

Control measures tested: (1) Removal of affected leaves or portions of leaves—no control. (2) Thorough poisoning of chewing insects—no control. (3) Spraying with Bordeaux plus a spreader—no control. (4) Seed and seed bed treatments—good control in several experiments. (5) Applications of lime and fertilizer influenced the amount of disease.

Control of black-rot and black-leg of cruciferous crops by seed and seed bed treatments.
E. E. CLAYTON.

Bacterium campestre infected brussels sprouts seed and *Phoma lingam* infected cabbage seed were subjected to the following treatments with disease control as noted:

	Primary Systemic Black Rot	Black Leg
(1) Check	37.8%	24.5%
(2) HgCl ₂ : 1 to 1000 seed soaked 30 min.	18.6	3.0
(3) & (4) Hot water 50 C. seed soaked 25 and 33 min.	0	0.3
(5) HgCl ₂ : 1 to 1000 applied 3 times to plants in bed as for maggot control	0	2.4
(6) Bordéaux 4-5-50 applied same as (5)	22.3	4.5

Lots (3) and (4) stood transplanting with the least loss and made the most uniformly vigorous growth in the field.

Relation of soil temperature and soil moisture to infection by Plasmodiophora brassicae.
JOHN MONTEITH, JR.

The influence of soil temperature and soil moisture on the development of clubroot on cabbage seedlings has been studied in the greenhouse using naturally infested soil at constant temperatures and with constant soil moisture throughout the experiments. Soil temperature appeared to have little influence on the development of clubroot except as it influenced host development. Clubbing occurred at all temperatures favorable for cabbage growth with the same optimum temperature for the disease as for normal host growth. Soil moisture was found to be a more influential factor than temperature in clubroot infection. In soil kept at a moisture content below 50% of the water-holding capacity the disease did not develop even though there was sufficient moisture for cabbage growth. Infection occurs with moisture from about one-half the water-holding capacity upwards, and the severity of the disease increases with the higher moisture content up to saturation. The disease may develop on the roots without severely checking the growth of the plant when the soil moisture is limited, but when the soil moisture is excessive the diseased roots are soon destroyed by secondary decay organisms and the plant dies.

Effect of the mercuric chloride treatment for maggot on Rhizoctonia and club-root of cabbage.
W. O. GLOYER AND H. GLASGOW.

During the past three years of work on maggot control, it has been observed that mercuric chloride (1-1280) applied to cabbage seedlings reduced Rhizoctonia as well as maggot. In 1923 various maggot treatments were applied to four plantings (one each on clay and sandy soil and two on loam). A typical example of mercuric chloride plat where 1, 2 and 3 applications were made showed respectively 18 per cent, 4 per cent, and 2 per cent Rhizoctonia, while the check showed 59 per cent infected. Where tobacco dust controlled the maggot 83 per cent showed Rhizoctonia.

A similar planting test of 30 plats was made on a seed bed thoroughly infested with *Plasmodiophora brassicae*. Solutions of calcium hydrate, copper sulfate, ammoniacal copper carbonate and copper lime dust (13-87) had no effect on club-root. With mercuric chloride no club-root was found when only one application was made to the seedlings. This method of treatment appears a promising one for general soil sterilization when a plant needs the temporary aid of a fungicide while passing through a critical period of susceptibility to infection.

Susceptibility of species of Allium to onion smut. P. J. ANDERSON.

The usual explanation of the origin of onion smut is that it existed on some wild species of *Allium* before it migrated to the cultivated form. This explanation presupposes that there are other species which are susceptible. In order to determine whether such is the case seed from as many species of *Allium* as could be secured were planted in soil heavily infested with *Urocystis cepulae*. When the seedlings came up they were examined for smut lesions and the percentage of infection recorded. Sixteen of the 18 species tried were found to be susceptible to smut. *A. Cepa*, *Porrum*, *fistulosum*, *nutans* and *lobani* are very susceptible. *A. nigrum*, *obliquum*, *ampeloprasum* and *Hookeri* are fairly susceptible. *A. polyphyllum*, *Scorodoprasum*, *rothynicum*, *fallax*, *daravasicum*, *sibiricum* and the Winterbeek onion are resistant but not immune. No smut occurred on *A. Orcoprasum* and *A. moly*.

Temperature relations of Urocystis cepulae (Frast). J. C. WALKER AND F. L. WELLMAN.

The relation of temperature to germination and growth of the onion smut fungus has been studied. Chlamydospores and the "hyphal fragments," the latter assuming certain functions of sporidia, germinate best at about 15° C. The minimum temperature for both is slightly below 9° C. Above 27° germination is meager, an occasional chlamydospore germinating at 30° to 32°. Growth of mycelium on favorable medium, such as onion agar, is best at about 22° and almost as good at 25°. There is decided reduction of growth at 27° and it practically ceases at 30° C. It would appear, therefore, that the inhibition of infection previously noted (Jour. Agr. Research **22**: 235. 1921.) at a soil temperature of 29°, or above, is due largely to the direct inhibiting effects of higher temperatures upon the development of the parasite.

Occurrence of white rot of Allium (Sclerotium cepivorum Berk.) in Europe and America. J. C. WALKER.

This disease is commonly destructive to onion and leek in the British Isles, Holland and France, and to garlic in Spain and Italy. The causal fungus has undoubtedly been introduced to this continent repeatedly with bulbs of onion and garlic. However, only two authentic reports of its occurrence in America have been made, from Oregon in 1918 (identified by Prof. Whetzel) and from Norfolk, Virginia, in 1923. In southern and northern Europe the disease is most destructive during the cooler spring or autumn periods. The causal fungus attacks all subterranean parts of the plant, eventually destroying roots and bases of the scales. Characteristic minute black sclerotia are formed abundantly within or upon the decaying host tissue. Laboratory studies show the organism to be favored by comparatively low temperatures. On potato agar most rapid growth is at 20° to 23° C. with a maximum at about 28°. Most vigorous infection takes place, however, at soil temperatures at 12° to 18°; much less occurs at 22° and practically none at 26°. It is to be expected that the disease would develop most readily in our southern sections where onion, garlic, and shallot are grown as winter crops.

A Fusarium bulb rot of onion. E. C. TIMS AND J. C. WALKER.

A *Fusarium* bulb rot of onion is commonly destructive in the onion set growing section of Illinois. It appears a few weeks before harvest and continues through the storage period. Infection ordinarily takes place at the stem plate and causes a dry to semi-watery decay of the scales, with yellowing and premature dying of the tops. In

August, 1921, a species of *Fusarium* was isolated from typical specimens of the disease and its pathogenicity was proved by wound inoculation of mature bulbs and growing plants. The temperature range for the disease both in storage and in soil is from 14° C. to 32° C., or above, with optimum development at about 26° C. The optimum temperature for growth of the fungus on potato dextrose agar is also about 26° C. Soil moisture has no direct effect upon the development of the disease under greenhouse conditions. The causal organism belongs to the section *Elegans* of the genus *Fusarium*. It apparently agrees except for certain minor characters with the rather inadequate description given for *Fusarium cepae* Hanzawa (Myc. Cent 5: 4. 1914).

Bean wilt (Bacterium flaccumfaciens Hedges). Further studies. FLORENCE HEDGES.

A wilt of navy bean was briefly described in *Science* in April, 1922. Field and greenhouse experiments have proved that the disease is seed borne and that the causal organism may live inside and on the surface of the seed and retain its virulence for at least five years. The parasite has been isolated from seed from Michigan, South Dakota, Montana, Maryland, District of Columbia, France and Germany. (Seed from seedsmen except in first two.)

The disease is primarily a wilt but it is occasionally accompanied by yellowing. No stomatal infections have been obtained.

Pods containing infected seed may appear perfectly sound or the infection may be seen following the suture bearing the seeds, sometimes broadening out from it somewhat. In immature pods the diseased area may be yellowish green and somewhat withered. Sometimes it appears more or less water-soaked. It is more conspicuous on the mature pods, the diseased area being discolored (greenish brown) while the rest of the pod is yellow.

Diseased seed may have a thick, bright yellow, bacterial layer beneath and showing through the seed-coat, or may be covered with slime externally or have only a small amount at the hilum. They resemble seeds infected with *Bacterium phaseoli*.

The effect of late planting on the bacterial blight of beans. W. O. GLOYER.

Wells' red kidney beans have been planted in parallel rows at intervals of ten days from May 29 to July 1, since 1917. Late plantings showed less disease than early plantings. For Geneva, N. Y. plantings made June 15 or later were free from weevil insect punctures (dimples) and least subject to blight. Two periods of susceptibility to blight were observed. The first period begins with the germination of diseased seed and ceases with the formation of the third leaf. The second period begins at pod formation and continues until maturity. Some resistant varieties and crosses owe their resistance to the delay of pod formation until the cool days of September.

Flowers and pods were picked from a hundred foot test row of red kidney beans on July 23, 27, Aug 10, 17 and 23, 1923. At the last picking, the plants of this row were free from blight while 95 per cent of those of the next row, the check, were diseased. After 25 days without picking the test row showed a condition noted Aug 23 on the check. This indicates that susceptibility to bacterial blight occurs when there is maximum translocation of nutrients.

Soy bean pustule. Comparative studies with Bacterium phaseoli sojense Hedges and Bacterium phaseoli E. F. S. FLORENCE HEDGES.

This disease, briefly described in *Science* in July, 1922, has been found on a large num-

ber of varieties of soy bean and is known to occur in Texas, Virginia, Louisiana, South Carolina and Kansas. Cross inoculations with *Bacterium phaseoli sojense* and *Bacterium phaseoli* E. F. S. showed that the former will infect *Phaseolus* but is much more infectious to soy bean while the latter is only very weakly pathogenic to soy bean. Spray inoculations made with *Bacterium phaseoli* E. F. S. on soy bean seedlings or older plants in an inoculating cage produced little or no results but excellent infections were obtained on the cotyledons of seedlings grown in damp chamber and inoculated therein as soon as they had germinated. No pustules have ever been observed in inoculations with *Bacterium phaseoli* E. F. S.

There is some evidence that passage through *Phaseolus* increases the virulence of *Bacterium phaseoli sojense* for the same. It produces no pustules but an infection resembling that caused by *Bacterium phaseoli* E. F. S.

The colonies of *Bacterium phaseoli sojense* on beef agar plates are commonly characterized by striking internal convolutions sometimes visible to the naked eye. It is often impossible to obtain the organism from dried leaves although it has been obtained from herbarium material 8 months old.

A new downy mildew on soy beans. S. G. LEHMAN AND FREDERICK A. WOLF.

A leafspot disease of soy bean caused by one of the downy mildews has been observed in several localities within North Carolina. The disease may be recognized by the presence of indefinite chlorotic areas which change to grayish brown irregular lesions with well defined dark brown borders. A dense grayish coating of conidiophores may cover the lower surface of the lesions. The causal organism is a species of *Peronospora*, which when compared morphologically with previously described species on legumes is manifestly distinct. It is accordingly described herein as a new species and is given the name *Peronospora sojae*.

Tomato wilt. R. P. WHITE.

Resistant varieties of tomatoes developed by numerous institutions have met with varying degrees of success in Kansas. The Louisiana Red and Pink varieties have proven the most resistant. From a limited amount of data, there are indications that resistance is recessive. Selections made from resistant individuals of a cross between a resistant and a susceptible parent in the F_2 generation have proven resistant in both the F_3 and F_4 generations. High soil temperatures have been found to increase the severity of the disease. Using a soil composed of one quarter sand and three quarters garden loam, it was found that soil moistures below 17 per cent of the dry weight and above 27 per cent of the dry weight prevented infection. The optimum soil moistures for infection were found to be between 20 and 25 per cent of the dry weight.

Some new methods and results in the control of lettuce diseases with formaldehyde. W. S. BEACH.

During three years in the culture of lettuce under sash near Philadelphia, Pennsylvania, sterilization of seed beds with formaldehyde—1-100 dilution applied a gallon to the square foot—decreased "drop" to losses of 1 to 3 per cent as compared with 8 to 35 per cent on unsterilized soil.

Aiming to reduce the excessive labor of applying a 1-100 dilution with watering-pots, experiments in applying the same amount of formaldehyde to like areas in dilutions of 1-33, 1-25 and 1-16 were conducted. more water to drench the soil being added with a

hose or portable Skinner irrigation. The results were 3.5 to 12 per cent infection as compared with 20 to 60 per cent on check plots. A large factor in the lower degrees of control was *Botrytis* sp., it being controlled to a less extent than *Sclerotinia libertiana*. While the efficiency of these treatments was not ideal, the results were remunerative and large-scale application was possible.

In transplanting lettuce to the field in early spring, increases in marketable product of 14 to 51 per cent were obtained by the use of seedlings from sterilized seed beds, although the seedlings were set in unsterilized soil. These increases arise from the seedlings escaping infection by *S. libertiana*, *Botrytis* sp., *Rhizoctonia* and probably other fungi.

A Sclerotium disease of Yautia. MEL. T. COOK AND RAFAEL A. TORO.

The Yautia (*Xanthosoma* sp.) is grown extensively in Porto Rico. During the past few months numerous reports of disease have been reported to the writers. It was at first supposed that this disease was due to an organism found by our predecessor, Mr. J. Matz; but study showed that most of the trouble was due to a *Sclerotium* which is the same or very similar to *S. Rolfsii*. Experimental work has demonstrated that this organism will attack the growing plants and cause a very rapid decay, but we have not as yet determined whether a wound is necessary. Mr. Matz left preserved material showing a *Monilia*-like organism but we have not yet been able to locate this organism in growing plants. We have also found a few cases of a decay apparently due to a different fungus but have not as yet determined its character.

Studies on Fusarium wilt of spinach in Texas. J. J. TAUBENHAUS.

During the last three years, the writer has come across a wilt of spinach which he has studied and which he found to be caused by a species of *Fusarium*. Recently, Hungerford has described a *Fusarium* wilt in Idaho which he named *Fusarium spinaceae*. From our own work, it seems that the spinach *Fusarium* in Texas is different from that in Idaho.

In addition to studying the pathology, morphology, and physiology of the causal organism, several varieties of spinach have been planted on badly infected soil. Of the many varieties tested, the New Zealand spinach was found to be very resistant.

An apple stem tumor not crown gall. NELLIE A. BROWN.

Apple stem tumor has been considered a type of crown gall by pathologists, entomologists and orchardists for a good many years. The crown gall organism, *Bacterium tumefaciens*, was isolated from galls at the crown of apple trees and from the hairy roots of apple trees by the writer in her early work with crown gall diseases. (These were proved, by inoculations.) The stem tumors were worked over occasionally but *Bacterium tumefaciens* was not isolated. However, the writer considered the disease a form of crown gall. In 1923 an extensive study of the disease was undertaken. Abundant material was received from various parts of the United States from which several hundred plates were poured. Sometimes colonies resembling those of *Bacterium tumefaciens* appeared on the plates. These, however, did not prove to be the crown gall organism as shown by culture or inoculation tests.

The presence of woolly apple aphid on stem tumors and on the numerous small swellings in the axils of the leaves appeared suspicious. Orchards were examined where stem tumors were abundant and the woolly apple aphid was found on the trees and on

the tumors themselves. Root galls produced by the woolly aphid were on the majority of these trees. While the fact of their responsibility has not been proved, the evidence is strong.

Relations of temperature and moisture to the development of crown gall. A. J. RIKER.

Experiments with crown gall conducted on tomato indicated that the size of galls developed on stems under soil, which was kept at 14°, 18°, 22°, 26°, 30°, and 34° C., increased with the temperature up to about 22° and then decreased. Considerable inhibition appeared at 30° and above. On stems in the air no galls were secured at temperatures above 32°. Galls developed in soil in a series of containers, in which the moisture content was regulated at 20, 40, 60, and 80 per cent respectively of the water-holding capacity of the soil, showed larger size with increased moisture up to 60 per cent. Those developed in soil containing 80 per cent moisture developed about as those in 40 per cent. The increased size of galls with higher temperatures and larger amounts of moisture was partly correlated up to 22° with the greater size of the plant. The tallest plants were secured at 30° and 80 per cent moisture, while the largest galls were found at 22° and 60 per cent moisture.

Strawberry leaf-scorch. FREDERICK A. WOLF.

This disease was first collected in Europe nearly one hundred years ago and has been known in the United States for nearly forty years. Collections have been made in New York, Connecticut, New Jersey, Indiana, West Virginia, Wisconsin, Montana, Maryland, Louisiana, Tennessee, Florida, and North Carolina. It is regarded as the most destructive disease of this crop in North Carolina.

Purplish to reddish lesions which coalesce and involve the entire leaf surface give to the plant a burnt appearance, hence the common name. Affected plants may be weakened and succumb during summer. The disease appears also upon petioles, fruit pedicels and calyx lobes. The impairment of the fruit results largely from the infection of the calyx.

The organism has two stages, acervuli which are subcuticular of the Marsonia type and ascocarps. Connection between the stages has been demonstrated by the appearance of both on the same lesions, by growth in pure culture and by inoculation experiments. Species of *Potentilla* are not subject to infection by this organism. Study of the morphology and development of the ascocarp shows that it is one of the *Phacidiales*, not one of the *Periziales* as has hitherto been believed.

The grey bulb-rot of tulips. H. H. WETZEL AND JOHN M. ARTHUR.

This disease long known in Holland and Germany as the sclerotium disease of tulips is here reported apparently for the first time from America. The identity of the pathogen with the fungus described by Klebahn as *Sclerotium tuliparum* has been established. A critical study of the fungus indicates that it is a *Rhizoctonia* rather than a *Sclerotinia* as suggested by Klebahn. The organism is therefore transferred to the former genus under the name *Rhizoctonia tuliparum* (Klebahn) nov. comb. No perfect stage has been discovered.

Soil disinfection experiments made in October, 1923, indicate that the fungus may be effectively eradicated from infested soil by the application of formaldehyde solution at the rate of 1 lb. (40 per cent) formalin per 5 square feet of soil surface. The drench used was made up at the rate of one part formalin to fifty parts water and was applied 12

days before planting the bulbs. Control plots showed in April, 1923, but 6 to 8 per cent of a stand while the treated plot gave a stand of 96 per cent.

A sclerotial disease of cultivated Delphinium. D. S. WELCH.

Specimens of diseased Delphinium were sent to the Department of Plant Pathology at Cornell University from Long Island, N. Y., Pennsylvania, Indiana and New Jersey. The stalks and especially the crowns of these plants showed signs of the presence of some fungus. Sclerotia were found attached to the diseased portions and cultures from these as well as tissue plantings from the interior of the stalks yielded the same type of organism in every case. Growth on potato dextrose agar produced abundant white mycelium and a considerable number of sclerotia which were very irregular in shape and size, 0.1 to 1.5 cm. or larger and often coalescing in masses, white at first, changing through buff and tan to dark brown but never to black. Clamp connections were found in the mycelium. Inoculation experiments showed that the organism is readily pathogenic to both the annual and perennial varieties of cultivated Delphinium. The progress of the disease is very rapid, the lower leaves become slightly yellowed and the upper leaves may still be green and scarcely wilted when the plant falls over due to the death of the tissues at the crown. This fungus cannot be identified with any described species and the author proposes the name *Sclerotium Delphini* to designate this pathogene.

Notes on the Nematospora disease of lima beans. H. W. ANDERSON

A *Nematospora* closely resembling *Nematospora phaseoli* Winegard was found prevalent in a field in southern Illinois. The seeds were obtained about two years ago from California and the grower has used his own seed exclusively. No other beans have been grown in the neighborhood. Dried lima beans bought in a local (Champaign) grocery supposedly obtained from California in 1922 showed this disease. A survey of the large commercial lima bean sections should be made to determine the distribution of the disease and measures should be taken to prevent its introduction into new areas since infected fields are a total loss.

A cytological study of this *Nematospora* shows clearly its relationship to the true *Ascomycetes* but indicates some peculiar variations in the nuclear behavior.

Fusion of minute active cells indicates a true sexual conjugation, but the cells are so small that it is impossible to determine the nuclear behavior after fusion.

The name of the American brown-rot Sclerotinia. J. B. S. NORTON AND WALTER N. FZEKIEL.

For years the taxonomy of the *Sclerotinia* causing brown-rot of stone and sometimes pome fruits in America has been in doubt. Extensive cultural and inoculation experiments have confirmed the results of H. Wormald, and shown that the American species is distinct from not only the European *S. fructigena* but also from *S. cinerea*. The writers propose the name *Sclerotinia americana* (Wormald) comb. nov. for the common American species. (*S. cinerea* (Bon.) Schroeter, forma *americana* Wormald; Ann. Bot. **33**: 361-404. 1919, and **34**: 143-171. 1920.) This is the fungus widely destructive in this country, whose apothecial stage was described by Norton, and which was studied and described by Reade, Matheny, etc.

The species mentioned can be differentiated macroscopically on potato-glucose agar

plates by variations in the rate of growth, production of conidia and aerial hyphae, and shape and elevation of the colony.

Strains of the brown-rot fungus, Sclerotinia americana WALTER N. EZEKIEL.

Variation within the species of *Sclerotinia* causing brown-rot of stone and pome fruits in this country has been previously noted. In studies with single-spore strains extending over a period of more than three years, the writer has been able to prove by repeated series of cultures, inoculations, reisolation and reinoculation, that these variations are genetic characteristics of the respective strains and not responses to environmental influences. The cultural characteristics of *Sclerotinia americana* strains are, under given conditions, invariant for each strain. Continued cultivation under similar conditions does not remove distinctions between strains; nor has cultivation under different conditions induced variations within a single strain when it is again grown under uniform conditions.

Hyphal anastomosis may take place in agar plates at the junction of colonies of dissimilar as well as similar strains and species. It is suggested that strains may arise from such fusions within rotting fruits.

On the physiology of the genus Phytophthora. LEON H. LEONIAN.

Sixteen species of *Phytophthora* were grown in a nutrient solution of known composition; the vigorously growing mycelium was then washed in sterile distilled water and transferred to various solutions of one hundredth molar concentration. Nine sugars, six amino-acids, four organic acids, and two basic salts have been tried thus far. All of the organic acids and some of the amino-acids inhibited, more or less generally, the zoosporangia formation. The remaining amino-acids, the sugars, and the basic salts induced an abundant asexual reproduction. Single food constituents suppressed oogonia and stimulated zoosporangia, while a proper combination of these gave rise to oogonia as well.

Air supply constitutes the chief factor in reproduction. A lack of food was not found to be a controlling factor, since large quantities of zoosporangia formed even when the cultures were transferred to a fresh supply of nutrient solution every day.

Ten new synthetic and semi-synthetic solid media were developed and the organisms were studied in these. Not only the rate and the nature of growth, zoosporangia and oogonia production showed sharp specific characteristics, but the shape and size of the mycelium exhibited very profound and typical changes.

Spore germination of Phytophthora infestans. B. N. UPPAL.

Very little is understood regarding the effect of various substances on spore germination. Spores of *Phytophthora infestans* were placed under favorable conditions for germination, except that oxygen around the cultures was eliminated by an air pump, by the potash-pyrogallol method, and by its replacement with a nitrogen atmosphere. Germination occurred when air pump and nitrogen atmosphere were used. In the potash-pyrogallol method, when the desiccator was placed in the refrigerator immediately, there was some germination; but if the desiccator was held at 20° to 22° C. for a while before removing it to 10° C., germination became very doubtful. The absorption of oxygen is very slow in cool air, and it is also believed that by slow absorption of oxygen there is abundant production of CO.

High boiling products of crude petroleum—vaseline, paraffin-wax, and paraffin oil—stimulated germination, vaseline affording a remarkable stimulus. On the other hand, low boiling products—petroleum ether and gasoline—at the bottom of the moist chamber, inhibited germination; methyl alcohol and formaldehyde, under similar conditions, also inhibited germination. Vaseline more than offsets the inhibitory effect of gasoline, but in other cases the inhibition was complete.

The best germination occurred in 1 per cent of sugars. In 16 per cent, inhibition of germination is associated with high osmotic pressure, which brings about plasmolysis. Cellulose and sugars appear to act differently at about 2 per cent and lower concentrations.

Summary of investigations on clover rusts. W. H. DAVIS.

Results of observations, inoculations within the species and reciprocal inoculations with rust spores of *Uromyces* sp. removed from our common clovers, white, *Trifolium repens* L.; red, *Trifolium pratense* L.; alsike, *Trifolium hybridum* L. and mammoth, *Trifolium medium* L. are as follows:

1. The rust on white clover is autoecious, an eu form and a separate species, *Uromyces trifolii-repentis* (Cast.) Liro.

2. The rust on red clover is autoecious, an eu form and a separate species, *Uromyces trifolii* (Hedw. f.) Lév.

3. Mammoth clover is parasitized by *Uromyces trifolii* (Hedw. f.) Liro

4. The rust on alsike clover is autoecious, an eu type and a separate species, *Uromyces hybrida* Davis.

5. Sowings of aeciospores, uredinospores and teliospores from alsike clover failed to infect white, red, medium and crimson clover (*Trifolium incarnatum* L.) but infected alsike clover producing the characteristic spore forms.

6. The principal morphological difference noted is that the inner and the outer walls of the peridial cells in the aecium from *T. hybridum* are thinner than those of the aecia in *T. repens* and *T. pratense*. The morphological difference between the rust on *T. hybridum* and that on *T. repens* is more striking than between the rusts on *T. repens* and *T. pratense* which are classified as two different species

Conjugation in the aecium of Dicaeoma distichlidis E. J. PETRY AND LYNN D. HUTTON.*

From field observations of the senior writer, made in 1921, it was suspected that aecia found on leaves of *Steironema ciliatum* (L.) Raf. were caused by tolia on *Spartina cynosuroides* (L.) Roth. The latter were intimately mingled with young *Steironema* shoots whose lower leaves were affected. New infections on young leaves, after rains, explained this location of the first aecia found.

The rust, after further study, was referred to *Dicaeoma distichlidis* (Ellis and Ev.) Kuntze, whose aecial stage on *Steironema* had already been connected with the telial stage on *Spartina*.

Since the aecial material would lend itself to ordinary histological methods the writer decided to see if conjugation stages similar to those found in several rusts by other investigators exist here. Briefly stated, some of the results are as follows.

1. Pycnia and aecia arise from uninucleate mycelium and are functionally unrelated in aeciospore formation.

* Junior Author.

2. The aecial hymenium consists of the conjugated ultimate or penultimate cells of the subhymenium.
3. The size of the conjugation aperture through which one of the conjugating nuclei passes, varies in different cases.
4. "Trichogynal" and "buffer" cells of several authors were found. These disappear before maturity of the aeciospores.

An undescribed imperfect fungus associated with wheat foot-rot in Oklahoma. H. H. McKINNEY.

The writer found this fungus and also *Helminthosporium sativum* associated with a foot-rot of wheat grown near Woodward, Okla., in 1923. Young cultures of this fungus can not be distinguished macroscopically with certainty, from cultures of *H. sativum*. Older cultures of the undescribed fungus differ from the latter, however, in that they develop numerous sclerotial structures and a sclerotial crust on the surface of potato-glucose agar. The conidia are light to dark brown in color, elliptical in form, tri-septate, and are borne in clusters containing from two or three to fifty or more, on simple or branched conidiophores. Conidia produced on host tissue have been found to average $12 \times 30 \mu$ in size. From the standpoint of conidia this fungus might be classified as a *Helminthosporium* or a *Brachysporium*, depending on the point of view accepted.

Inoculation studies show that the fungus is parasitic on the underground parts of wheat seedlings. The type of injury resembles closely that produced by *Helminthosporium sativum*. The parasite is of unknown economic importance.

(Cooperative investigations by the Wisconsin Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Studies on predisposition of wheat and corn to seedling blight caused by Gibberella saubinetii.

JAMES G. DICKSON, SOPHIA H. ECKERSON, AND KARL P. LINK.

Wheat seedlings blight when grown in a warm soil, above 12° ; corn seedlings blight when grown in a cool soil, below 20° C. Wheat, therefore, is predisposed to blighting at the higher and corn at the lower soil temperatures. Limiting soil moisture or light intensity likewise predisposes the seedlings to blighting and limits their response to temperature.

Mycelial penetration, where no blighting occurs, is limited to a slow digestion of the middle lamellae, whereas, at temperatures favorable for blighting the cell walls are penetrated with seemingly little resistance.

The chemical nature of the germinating embryos apparently depends upon the kind of building substances available and their proportion one to another. Because there is an abundance of dextrin and sugar, and relatively little available protein material in the wheat embryos grown at the low temperatures, these plants have thicker, more resistant cell walls. At the higher temperatures, however, there is more rapid vegetative growth with less dextrin and sugar available for building and thickening cell walls. Likewise, because of an abundance of sugar and fat available in the corn embryos at the high temperatures, a carbohydrate reserve exists for building thicker, more resistant cell walls.

(Cooperative investigations by the Wisconsin Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Poria cocos developed on tuckahoe found attached to orange tree root. GEORGE F. WEBER.

Several tuckahoes were found, in June, 1923, attached to the roots of an orange tree near Gainesville, Florida. They varied in weight from 5 to 9 pounds and were irregular in shape. The outside covering was bark-like, brown and tough. It varied from 3 to 8 mm. in thickness. The inner texture was white, starchy, spongy and gave off a mushroom odor. One of these bodies was sterilized for twenty minutes in a 1-1000 solution of corrosive sublimate. It was then carefully washed in five changes of sterile distilled water and placed in a sterile moist chamber at room temperature exposed to intermittent light. After ten days a chocolate-brown fungous growth appeared in several places on the outside covering, this growth matted down and fruiting structures developed of a resupinate nature apparently that of a *Poria* sp. The pores were irregular, 2 to 4 mm. deep, and of a distinct chocolate-brown color. The basidiospores were greyish white $6-9 \times 2-4 \mu$.

Biological and cultural studies of Exoascaceae. I. Exoascus deformans (Berk.) Fuehler.

A. J. MIX.

Isolations were made from ascospore-bearing leaves and from the interior of diseased leaves and stems. Single-ascus cultures were used for study. On solid media a slow-growing, yeast-like, delicately pink colony is formed. Cells formed in culture are: budding "conidia," short mycelia, and "resting cells." In their germination resting cells resemble ascogenous hyphae.

Minimum temperature for growth is below 10°C ., optimum about 20°C ., maximum between 26° and 30°C .. Cultures are killed in a few days at 30°C .. The thermal death-point is 46°C .

Cells from culture survive desiccation on glass at temperatures of 9° , 22° , and 30°C .. for at least 140 days. The thermal death-point of cells in smears dried on glass is 100°C ..

Limits of growth on potato dextrose agar and in potato dextrose broth are beyond pH 3.3 and pH 9.6. On the agar best growth occurred at pH 4.9. In general the acidity of the broth was increased, but in broth with an initial pH of 3.9, no change occurred.

Inoculations performed out of doors on buds previously sprayed with formaldehyde were successful. Cultures twenty-two months old proved virulent. Attempts to inoculate very young seedlings failed.

Biological and cultural studies of Exoascaceae. II. Exoascus mirabilis Atkinson.

A. J. MIX.

Isolations were made from ascospore-bearing surfaces and from the interior of diseased shoots of *Prunus angustifolia*. The fungus grows well on various media. It cannot be distinguished by means of cultural characters from *Exoascus deformans*. Similar types of cells are formed in culture.

Limits of growth on potato dextrose agar are in the neighborhood of pH 2.6 and pH 11.2. Best growth occurred at pH 4.2. In potato dextrose broth, growth occurred at all concentrations tried between pH 10.45 and pH 3.28. No growth occurred at pH 10.90 and pH 3.06. Increased acidity occurred in all broth cultures except those with hydrogen-ion concentrations higher than pH 4.0; in these no change occurred.

Spraying dormant trees with lime-sulfur 1 to 20 prevents infection, indicating that some spore-form overwinters.

Sepal infection in relation to the seasonal development and control of apple scab. G. W. KEITT AND L. K. JONES.

Studies conducted during the last five years have shown that sepal infection bears very important relations to the seasonal development and control of apple scab, especially in seasons of severe outbreaks in early spring. Under Wisconsin conditions ascospores are ordinarily mature by the time the tips of the young leaves in the unfolding cluster buds are exposed to infection. The sepals are the first blossom parts so exposed and may be infected many days prior to the "pink" spray stage. Sepal infections establish the fungus on the young fruit in a most favorable position for early secondary infections. Such infections are much more injurious than those which develop later, and account for a large percentage of badly scabbed fruit. In our spraying experiments failure to control sepal infection has uniformly resulted in unsatisfactory control of the disease. A well timed "pre-pink" treatment with a suitable fungicide followed by the usual scab program has uniformly controlled the disease.

Seasonal development and control of apple scab and cherry leaf spot in relation to environment. G. W. KEITT AND L. K. JONES.

Comparative studies of apple scab and cherry leaf spot in Wisconsin have shown marked contrasts in their relations to environment. Although there was relatively little difference in the periods of ascospore discharge and in the time of exposure of susceptible host tissue to infection, there were marked contrasts in the seasonal development of the two diseases. In the case of apple scab, a low temperature disease, early discharges of ascospores commonly led to relatively abundant infection which established the fungus in a favorable position for secondary infection. The most critical period for the development of this disease was in the spring. It was retarded during the hot weather. Cherry leaf spot, a high temperature disease, made little progress during the cool period of early spring, but developed rapidly in early summer and attained its maximal development at summer temperatures. Accordingly, whereas it was formerly the practice in Wisconsin to make one pre-blossom fungicidal treatment for each of these diseases, it is apparent now that, under Wisconsin conditions, two pre-blossom treatments are necessary for satisfactory control of severe outbreaks of apple scab in early spring, while for cherry leaf spot the pre-blossom spray may be omitted.

Achyrodes aureum (L.) Kuntze, a host for many rusts. S. M. DIETZ AND I. W. CLOKEY.

According to Arthur, *Achyrodes aureum* (L.) Kuntze is susceptible to *Puccinia coronata* and *P. graminis*. The response of this gramineous host to the specialized forms of these rusts, however, was not determined. In studying the host range of the specialized forms of the crown-rust organism, *P. coronata*, *Achyrodes aureum* proved to be susceptible. *A. aureum* was exposed to all available rusts. Spores were transferred from their natural hosts to *A. aureum*, thence again to their natural hosts. *A. aureum*, a low erect annual, belongs to the tribe Festuceae. Its vegetative growth closely resembles that of *Dactylis glomerata*. Although indigenous to southern Europe, it has been introduced into many parts of the world, including Australia and southern California. *Achyrodes aureum* showed normal infection from uredospores of five specialized varieties of *Puccinia coronata*, namely: *P. coronata avenae*, *P. c. calamagrostidis*, *P. c. festucae*, *P. c. holci* and *P. c. lolii*; two specialized varieties of *P. graminis*: *P. graminis avenae* and *P. phleum pratense*; and three other species: *P. dispersa*, *P. montanensis*,

and *P. poarum*. A subnormal infection was secured with two specialized varieties, *P. graminis secalis* and *P. g. tritici*; and with *P. triticea*. *Achyrodes aureum* is susceptible to several species of Puccinia and their specialized varieties. It affords excellent material for a study of specific parasitism.

(Cooperative investigations by the Iowa Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

An abortive sporophore of Sclerotium rolfsii. J. J. TAUBENHAUS.

The writer has made numerous attempts to produce a fruiting stage of *Sclerotium rolfsii* without success. This fall (1923) several watermelon fruits were inoculated with a pure culture of *Sclerotium rolfsii*. In four weeks the inoculated fruit were thoroughly decayed and a large amount of liquid was liberated and drawn off. Suddenly it was noticed that a small mushroom-like body made its appearance and this after ten days grew and developed into a typical fleshy mushroom. Examinations were frequently made of this sporophore which was found to be sterile. Bits of tissue of this growth were then plated out in petri dishes to determine whether it was a secondary infection or a sterile sporophore of *Sclerotium rolfsii*. Growth and minute mushroom-like bodies appeared in the petri plates, these, however, in turn being also sterile and after three weeks matured into typical sclerotia of *Sclerotium rolfsii*. From work, so far, it seems that this is a strain of *Sclerotium rolfsii* which is apparently capable of producing sporophores which for some reason or other have remained sterile. More research is in progress on this point.

Wheat bunt investigations in Kansas. C. O. JOHNSTON.

Studies on the resistance of several varieties of wheat to bunt have been conducted three years. In two of these years duplicate sowings were made. In one the seed was smutted with spores of *Tilletia laevis* and in the other with *T. tritici*. Hard winter varieties of the Turkey type, as a group, show considerable resistance to both species causing bunt. Those soft winter wheats adapted to Kansas conditions are much more susceptible to *T. tritici* than to *T. laevis*. This is shown by the table which was prepared from the 1923 data

	Percentage of bunted heads, <i>T. laevis</i> .	Percentage of bunted heads, <i>T. tritici</i> .
Average of 20 hard varieties (Turkey type)	4 85	3 07
Average of 20 soft varieties	3 45	25.13

Varieties and hybrids from the Pacific Coast States, which are highly resistant under western conditions, show the same resistance to both kinds of bunt in Kansas. Of these, Red Hussar seems promising agronomically. Weekly sowings of a susceptible variety indicate that little infection takes place until the mean daily soil temperature has fallen to about 40° F. As the soil temperature falls below this point smut infection increases until a temperature of about 27° is reached. At both high and low temperatures the percentage of infection varies with the moisture content of the soil.

(Cooperative investigations by the Kansas Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Varietal resistance of winter wheats to Tilletia levis. G. H. COONS.

Results of two additional years' tests of resistance of winter wheats to *Tilletia levis* are now available. In the tests small samples of the various wheats were heavily dusted with *Tilletia levis* spores and planted about Oct. 15—the late planting insuring heavy infection by smut. The following table gives the per cent of smut in the crops as determined by head counts.

Variety	1922	1923
Shepherds Perfection.....	—	60%
American Wonder.....	53%	49
New Fultz.....	53	40
Illini Chief.....	53	—
Goens.....	50	46
Estes (240).....	48	36
Poole.....	46	43
Estes (139100).....	45	42
Michigan Wonder.....	44	—
Iowa 1946.....	—	40
Red Champion.....	39	19
Early Winter.....	39	47
Red Banner.....	39	26
Economy.....	35	46
New York 26.....	33	51
American Banner.....	31	55
Genesee 140900.....	30	66
Winter King.....	27	33
Lancaster 136200.....	26	42
Wonder.....	24	22
Red Rock.....	24	21
Lancaster 138700.....	23	27
Michigan Amber.....	22	30
Turkey.....	20	15
Banner American.....	19	0
Kharkof.....	15	9
Kanred (a).....	12	0
Wisconsin Hybrid.....	11	21
Berkeley Banner.....	10	18
Genesee 141600.....	9	22
Turkey 138300.....	9	5
Kanred (b).....	7.7	8
Alberta Red.....	6	7
Fultz 139400.....	4	6
Berkeley Favorite.....	2	0.8
Berkeley Rock 140200.....	1	1.6
Minhardi (Minn 1505).....	1	—
Berkeley Rock 128700.....	0.6	0.3
Berkeley Rock 133300.....	0.4	0.4
Red Winter.....	0.2	—

Berkeley crossed with American Banner, Favorite, and Red Rock seems, to have given marked stinking smut resistance to its progeny. All the wheats, except Fultz, which have shown the strongest resistance to *Tilletia lens*, are Turkey wheats or selections from crosses with this type. The wheats resistant to *Tilletia tritici* recently reported in the literature are of similar origin.

Physiological studies on flag smut of wheat. MARION A. GRIFFITHS.

Experiments conducted by the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, show that spores of flag smut, *Urocystis tritici* Keke. kept in the laboratory were viable for at least four years. Spores overwintered in the soil at Granite City, Ill., were capable of infecting wheat. For infection in the greenhouse the optimum temperature was 20° to 23° C. Infection takes place most readily prior to emergence of the seedlings from the soil. Inoculated plants were clipped near the soil at three stages of growth. Clipping often increased the percentages of infection. Also, the interval between sowing and the appearance of infection often was shorter in the clipped plants. Fulcaster, Poole, Red May, Red Rock, Early Defiance, and Galgalos remained smut-free in the greenhouse during each of the three years of the varietal-resistance experiment. The percentages of infection shown by susceptible varieties grown in the greenhouse were considerably higher than those of the same strains grown in the field. Sowing inoculated seed at successive dates in the fall resulted in a general decrease in the percentages of infection up to November 14, when no infection occurred.

Puccinia graminis on Poa spp. in the United States. E. C. STAKMAN AND M. N. LEVINE.

Heavy infection of stem rust on *Poa* spp. in the United States was first observed in the fall of 1922 near Pontiac, Mich. Previous to this date *Puccinia graminis poae* was generally thought not to occur in this country. Several specimens of what appeared to be *P. graminis* on *Poa* spp. have been sent to the writers, but the amount of rust always was small and no infection was obtained from artificial inoculations. Abundant and heavy infection was produced on the common barberry when inoculated with teliospores from *Poa compressa* collected in Michigan. Aecial inoculation resulted in heavy infection on at least three species of *Poa*, but no infection on other grasses or on the cereals. In 1923, *Poa compressa*, near Pontiac, again was badly rusted. As a result of urediniospore inoculations, successful, normal infection was obtained on three additional species of *Poa*. Minute pustules were produced on barley also, but negative results were obtained on the other cereals and grasses. Measurements of the aeciospores, urediniospores, and teliospores of this specialized variety show it to be markedly different morphologically from any other specialized variety of stem rust.

(Cooperative investigations by the Minnesota Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Cytological evidence of physiological distinct forms in Puccinia graminis tritici. RUTH F. ALLEN.

Stakman and Levine have proved the existence of physiologically distinct specialized forms of wheat stem rust. These forms, which are designated by number, are similar in morphology but differ in infecting power. Specialized form III grown on Kanred

seedlings in the greenhouse produces a fairly vigorous mycelium which fills intercellular spaces in the mesophyll, forms normal haustoria and "runners," and produces mid-size uredinia. Form XIX on Kanred can not form spores or even establish a mycelium. The fungus may die after forming the first haustorium, or may make several attempts before its strength is spent. Forms IX, XXI, and XXVII, grown on Khapli under parallel conditions, are similar in many respects, but differ in their effect on the stomata through which they enter the host, in the rate and extent of spread of the mycelium, in the modification of the haustorium mother cells of the fungus, and in spore formation. Changes induced by these fungi in the zone of tissue surrounding an infection vary as to the size of the region affected, the time of its appearance, the degree to which it is affected, the plasmolysis of its cells, and the staining reaction of its plastids.

(Cooperative investigations by the California Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Simultaneous surveys for stem rust: A method of locating sources of inoculum. E. M. FREEMAN AND I. W. MELANDER.

The use of simultaneous surveys of large or small areas to locate incipient local epidemics of stem rust and such common barberry bushes as may have escaped detection during the first surveys and resurveys is recommended. A study was made of the possibilities of simultaneous surveys in Minnesota in July, 1923. These surveys showed consistent differences in the rust severity in different localities of the district examined, although the rust epidemic was too far advanced to permit any correlation with the barberry as a cause of the differences. The use of winter rye and grass hosts as indicators in such surveys also is suggested.

(Cooperative investigations by the Minnesota Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Progress in barberry eradication. F. E. KEMPTON.

The barberry eradication campaign, conducted cooperatively for the past six years by the United States Department of Agriculture and thirteen north-central States, has progressed until approximately 656 counties have been surveyed. This includes a property-to-property survey of all cities and an inspection of all farms in these counties.

A summary of activities to October 31, 1923, shows a grand total of 9,726,348 common barberry bushes and seedlings found and 8,071,932 destroyed. During this season, 208,956 bushes and 1,706,027 seedlings were found in original survey and 215,366 bushes and 1,701,122 seedlings destroyed, while in resurvey of 299 counties, 102,066 sprouting bushes and 909,607 seedlings were destroyed.

Crushed rock salt proved the safest and most readily obtainable chemical for killing barberries. Over 400 tons were used. Sodium arsenite solution, while effective, proved dangerous to animals. Its use was discontinued. Kerosene and water-gas drip oil also are effective. Chemicals can not be applied safely near valuable trees or shrubbery.

A second survey of several previously covered counties showed plantings in each county not found on the first survey. In many counties these were sufficiently numerous to be responsible for initiating the rust epidemic of 1923. This shows the necessity of a second survey of some areas.

Studies in distribution and severity of rust, and resultant losses were continued. Local rust epidemics have enabled field men to find overlooked barberries.

Epidemiology studies with Puccinia coronata Corda S. M. DIETZ.

Since 1916 aecidial infection of *Puccinia coronata* has appeared annually in Iowa on *Rhamnus cathartica* L. and *R. lanceolata* Pursh before uredosori developed on *Avena sativa*. The date of initial appearance of aecidial infection during these 8 years varied from April 30 to May 30. During 1923 many local crown-rust infections appeared on oats throughout the State previous to the general infection. Either *R. cathartica* or *R. lanceolata* was found near the center of each infected area. Infection varied from a trace on the edge of these areas to 30 per cent near the center. These infection areas developed simultaneously in northern and southern Iowa. All, at first small, remained constant 7 to 10 days, then expanded rapidly.

Eight hundred and twenty plantings of *R. cathartica* were found in representative areas in eight midwestern States. Of this number 188 were rural and 632 were urban. They contained 89,496 bushes, besides 34,018 feet of hedge of uncounted bushes. Over 80 per cent of all *R. cathartica* inspected bore crown rust aecidia. Nearly 100 per cent of rural plantings showed infection. In one area at Winthrop, Buchanan County, Iowa, outfields adjoining a hedge of *R. cathartica* were destroyed by rust. Fields in adjoining sections yielded 10 bushels per acre while fields in more remote sections practically free from rust averaged 50 bushels per acre.

(Cooperative investigations by the Iowa Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

The rate of spread of wheat foot-rot in tillage plots in Kansas. L. E. MELCHERS AND M. C. SEWELL.

In 1921 wheat foot-rot was observed in tillage plots. The diseased areas were carefully plotted and their rate of spread has been recorded each season.

Continuous wheat culture 1911-1923	First appearance foot-rot	Average yield prior	Yield	Disease
		1921	1923	1923
		bu.	bu.	
Not plowed; disked at seeding		6.4	2.5	None
Plowed Sept.; 3 inches (5 replications)		12.3	7.8	None
Double disked July; plowed Sept., 7 inches	1922	17.2	26.8	Very slight
Double disked July; plowed Aug., 3 inches	1922	17.9	17.2	Slight
Listed July; ridges worked down	1922	17.9	18.6	do
Listed July 15; ridges split Aug. 15	1922	17.4	9.2	Very bad
Plowed July; 6 inches	1921	19.2	12.7	do
Plowed Aug.; 6 inches	1921	18.4	6.0	do
Plowed Aug.; 7 inches worked Sept.	1921	17.6	18.9	Bad
Plowed Sept.; 7 inches	1923	13.1	10.4	Very slight
Plowed July; 3 inches		17.5	18.6	None

Ophiobolus cariceti (B. & Br.) Sacc. has been found on plants from various plots. Early, deep (6-7 inches) plowing or listing seems favorable for the development and

spread of foot-rot. **Late**, shallow (3 inches) plowing or disking inhibits it. Where wheat has been grown in rotation in adjoining land there has been no evidence of foot-rot.

(Cooperative investigations by the Kansas Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

New seed treatments for controlling stripe disease of barley. A. G. JOHNSON, R. W. LEUKEL, AND J. G. DICKSON.

During the past season certain new seed treatments for control of stripe disease of barley (*Helminthosporium gramineum* Rabh.) were given preliminary trials at Arlington Experiment Farm, Va., and Madison, Wis. Treated and untreated seed was sown in adjacent rod rows in triplicate. Treatments listed in following table controlled barley stripe perfectly and seed germination was not impaired.

Chemical	Concentration in water Per cent	Time Hours
Semesan	0.3	1, 2
do . . . . .	.6	1/2, 1, 2
Chlorophol . . . . .	.2	1, 2
do	3	1/2, 1, 2
do	6	1/2, 1, 2
Germisan . . . . .	.2	2
do	3	1/2, 1, 2
do . . . . .	.6	1/2, 1, 2
Corona No. 610 . . . . .	.2	1/2, 1, 2
do	3	1/2, 1, 2
Corona No. 620	2	1, 2
do . . . . .	.3	1/4, 1/2, 1, 2

Similar treatments with kalumet and formaldehyde solutions reduced the disease to a trace, while pythal solution and seed-o-san and copper carbonate dusts failed to control. Unfortunately uspulun was not available for these experiments. Rows from untreated seed averaged between 5 and 6 per cent stripe.

(Cooperative investigations by the Wisconsin Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Comparative efficiency of formaldehyde, copper-carbonate dust and sulfur dust in controlling smuts in hulled oats R. S. KIRBY.

The following data were obtained from 19 experiments planted in 12 counties in New York State in 1923. Each experiment, consisting of 1 check and 2 to 5 treated plots, each of which averaged one-eighth acre in size, was planted with naturally inoculated oats from different sources. Seed treatments were usually made by county agents using identical materials. While the percentage of smut in the various check sections of the plots varied from .5 to 44.1 per cent, the percentage of smut eliminated by the various treatments was relatively the same.

Treatment	Average percentage of smut in checks	Average percentage of smut in treated plots	Percentage of smut eliminated by treatment	Odds compared with formalde- hyde	Odds compared with 4 oz. CuCO_3
Formaldehyde (dry)	8.50	4.12	95.56 \pm 1.82		14:1
Copper-carbonate dust (4 oz.) per bu.	10.90	1.50	88.10 \pm 1.82	14:1	
(2 oz.) " "	11.33	2.54	75.60 \pm 2.59	19,000 \pm 1	116 \pm 1
Dusting Sulfur (1 lb.) per bu.	15.80	5.18	59.10 \pm 5.11	19,000 \pm 1	267 \pm 1
(4 oz.) " "	9.54	5.40	49.58 \pm 8.81	1,350 \pm 1	260 \pm 1

Since significance can not be placed on odds less than 30:1 the tabulations show for the conditions of this experiment (1) formaldehyde is not with certainty a better treatment than 4 oz. CuCO_3 , (2) formaldehyde is better than any other treatment excepting 4 oz. CuCO_3 , (3) 4 oz. CuCO_3 is better than 2 oz. CuCO_3 or the sulfur treatments.

Water and lime-water baths following the formaldehyde seed treatment. W. H. TISDALE AND R. W. LEUKEL.

In Sweden, Henning (1919 and 1922) found that the injury caused to seed grain by the formaldehyde treatment was eliminated by rinsing the treated seed in water. In 1921, Zundel and Carroll recommended rinsing grain in lime-water following formaldehyde. The Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, is conducting experiments to determine the relative value of these methods. Spring-sown Kherson oats, soaked 10 minutes, 30 minutes, and one hour in formaldehyde (1-320), germinated in the soil slightly better when rinsed (soaked 10 minutes) in lime-water than when rinsed in water for the same period. In both cases rinsed seed germinated much better than did unrinsed treated seed and about as well as did untreated seed. The smuts were controlled satisfactorily with all the treatments. Fall-sown Winter Turf oats and Purplestraw wheat, when soaked 30 minutes in formaldehyde (1-320), gave approximately the same percentages of germination when rinsed in water as when rinsed in lime-water. The percentages of germination were about the same as those of untreated seed and much better than those of unrinsed treated seed. Either water or lime-water prevented a greater part of the injury.

Further studies on new seed disinfectants. W. H. TISDALE, J. W. TAYLOR, AND R. W. LEUKEL.

Since reporting on this subject in 1922, the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, has conducted further experiments with new seed disinfectants, including American and foreign products, to determine their relative effects on germination, vigor, and smut control of the small grains, as compared with the standard treatments. Of the dusts, copper carbonate, Corona No. 40-S, and Seed-O-San controlled bunt or stinking smut of wheat satisfactorily without injuring the seed. From the standpoint of yields, copper carbonate and No. 40-S were slightly better than copper sulphate-lime. None of the dusts has given entirely satisfactory results in the control of barley and oat smuts. Of the liquids, the organic mercury compounds, Chlorophol, Semesan, Corona No. 620, Uspulun, and Germisan,

have given good results in the control of barley and oat smuts. Germination and yields also were improved. Barley grown from seed treated with either Semesan or Chlorophol yielded better than did plants grown either from untreated seed of the same lots or from seed treated by any other method. For the control of barlet smuts results with these compounds have been more satisfactory than those obtained with either formaldehyde or hot water.

Fungicidal treatments for the control of sorghum kernel smut. C. O. JOHNSTON AND L. E. MELCHERS.

Seed of Blackhull kafir, Pink kafir, Red Amber sorgho and Kansas Orange sorgho, heavily smutted with *Sphacelotheca sorghi*, and treated with various fungicides, gave the following results:

		Formaldehyde				Corona No 620	Chlor- ophol	Cu- SO ₄	2 ounces per bushel of dry			Check
Year	Per- cent- age of	1 pt to 15 gal	1 pt. to 30 gal	1 pt. to 30 gal	Dry; 3 cc. per qt seed, covered 5 hrs	(1-500) soak 1 hr.	(1 300) soak 1 hr	1 lb. to 4 gal. soak 15 min	Corona 40 S.	Seed- O-San	CuCO ₃	
		10 min.	30 min.	60 min								
1921	Germin- ation Smut.	81 7 0 0	79 2 0 0	81.7 0 0								85 8 29.26
1922	Germin- ation Smut.	87 3 1 61	94 9 3 75	93 1 3 02	80 8 0 0	96 8 2 37	95.3 5.73	90 2 0 0	97 0 0.0	97 2 4 01		94 6 34 28
1923	Germin- ation Smut	78 9 0 23	80 4 1 12	81 6 0 16	77 8 6 04	85.0 1 86	92 5 0 49	80 6 0 24	91 9 0 53	89 7 6 93	89.6 0 28	89.7 13 38
	Average germi- nation											
		82.6	84 8	85 5	79 3	90 9	93 8	85 4	94 4	93 4	89 6	90 0
	Average smut	0 61	1 62	1 05	3 02	2 11	3 11	0 12	0 26	5 47	0 28	25 63

Slight seed injury occurs but satisfactory control of smut is obtained by soaking seed in copper sulphate or Chlorophol solutions, or by dusting with copper carbonate or Corona 40-S. Treatments conducted in various parts of Kansas indicate that copper carbonate dust is very promising.

(Cooperative investigations by the Kansas Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture)

Experiments to show the effects of certain seed treatments on corn. CHAS. S. REDDY AND J. R. HOLBERT.

In general there was a decrease in resulting field stands and yields from seed treated with formaldehyde (1 : 240 for 30 and 60 minutes), calcium hypochlorite (1 : 28 for 3

and 6 hours), mercury bichloride (1 : 1000 for 30 and 60 minutes), or copper sulphate (4 pounds to 10 gallons for 2 hours) with and without lime dip. No detrimental effect and frequently an increase in stand resulted from the use of chlorophol (1 : 400 for 3 hours) on composites of corn seed designated as nearly disease-free, *Fusarium*-infected, *Cephalosporium*-infected, *Diplodia*-infected, and scutellum-rotted. The most marked effect was from the use of chlorophol on *Diplodia*-infected seed; field stands and yields were always increased, often as much as 30 per cent. However, the same treatment apparently decreased the yields of *Cephalosporium*, *Fusarium*, and scutellum-rotted composites, sometimes as much as 13 per cent.

Chlorophol (1 : 400), semesan (1 : 400), and corona 620 (1 : 1000), when used as treatments for 3, 4, or 5 hours, proved beneficial to stands and yields of nearly disease-free composites as well as *Diplodia*-infected composites.

(Cooperative investigations by Funk Brothers Seed Company and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture.)

Second progress report on studies of corn seed germination and the prevalence of Fusarium moniliforme and Diplodia zeae. L. F. MELCHERS AND C. O. JOHNSTON.

Three years' germination studies with open pollinated Pride of Saline corn, corroborates the report made by the writers in 1922, that practically every ear of Commercial White and Pride of Saline corn has *Fusarium moniliforme* or *Diplodia zeae*, or both present. The latter organism varies in prevalence during different seasons, but the former is always abundantly present. The freedom of seed on the germinator from *F. moniliforme* does not seem as important in securing a satisfactory stand and yield of corn in Kansas as seedling vigor.

The following table shows results of germination of best ears which were selected for seed. These were taken from bin in 1920 and 1921 and from field in 1922. These data have been confirmed by cultures from hundreds of kernels representing large numbers of ears.

Year	Tested	Number of ears				Number of kernels			Av. germination
		With <i>F. moniliforme</i>	With <i>D. zeae</i> *	With all kernels diseased**	With less than half kernels diseased	Tested	With <i>F. moniliforme</i>	With <i>D. zeae</i>	
									<i>p. ct.</i>
1920-21	703	410		699	4	7030	6980		98.2
1921-22	1500	1357	143	1499	0	15000	14989	548	98.4
1922-23	1200	1176	24	1042	34	12000	10501	51	99.5
Av. per cent.		93.8	6.1	94.1	1.2		94.1	2.2	98.7

(Cooperative investigations by the Kansas Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

* Also may have had *F. moniliforme*.

** *F. moniliforme* or *D. zeae* or both

Common molds of corn seed in relation to yield. C. D. SHERBAKOFF.

The field experiments carried on by the writer at the Experiment Station, University of Tennessee, during the past two years, 1922 and 1923, show that corn seed when effectively treated against *F. moniliforme* does not give any better yield than the untreated seed of the same corn. To the contrary, the checks each year gave slightly better yield than the treated seed. The experiments were thoroughly checked up each year and the results of the first year are entirely in the agreement with results of the second year. The conclusion is that, under the conditions of the experiments, corn seed contamination with the mold has no effect on the yield. This situation may be due to either the non-pathogenic nature of *F. moniliforme*, in respect to corn roots, or that soil contamination with the fungus is so thorough and effective that seed freedom from it is of no consequence.

Relation of internal cob-discoloration to yield in corn. R. A. JEHLE, F. W. OLDENBURG, AND C. E. TEMPLE.

The butts and tips were chopped off from selected seed ears. Then, these ears were divided into at least two lots; those with distinct internal cob-discoloration, and those apparently free from internal cob-discoloration. Plots grown from each lot showed an apparent correlation between internal cob-discoloration and yield in corn which was more pronounced on light sandy and poor clayey soils than on the best corn land. This is indicated by the following table:

Year		No. of Tests	No. of counties	Average yield from corn on discolored cobs	Average yield from corn on cobs with no color	Average increase bushels	Average increase per cent
1921	Total	6	4	39.57	51.46	11.89	23.1
1922	Total	39	16	57.86	67.19	9.33	16.12
1923*	Total	15	8	65.25	58.33	6.92	11.86
1921	Very good corn land	1	1	60.4	63.3	2.9	4.8
1921	Medium to poor land	5	4	35.41	49.13	13.72	38.77
1922	Very good corn land	9	3	84.16	88.81	4.65	5.5
1922	Medium to poor land	30	15	51.39	60.86	9.47	18.43
1923*	Very good corn land	3	2	78.25	80.25	2.00	2.55
1923*	Medium to poor land	12	8	53.35	61.25	7.9	14.8

* Record incomplete.

Studies on seed infection, ear types, and yield, and the isolation of strains of corn showing specific disease reactions in the germinator. W. D. VALLEAU.

If germination tests of properly cured ears of corn are conducted in a sand box in a warm room, it will be found that the plants eventually die due to a rot starting at or

near the seed. The average time of death of the plants from a given ear may differ widely from that of other ears. In general the roughest ears produce the earliest dying plants. Selection of the extreme ears, i.e., those producing early dying and those producing late dying plants in the sand box, has given practically no differences in yield under field conditions, the "severely diseased" ears being as high producers as those which would commonly be called "disease-free." Selection for the extremes of smooth ears and rough ears from 500 and 700 ears of Boone County White in 1922 and 1923, respectively, resulted in increases of 39.43 and 13.9 per cent in yield for the smooth types over the rough. Studies on seed infection, both microscopically and by culturing, have shown that the seeds of the apparently most disease-free ears are quite heavily infected with fungi. By continued self-pollination, strains of corn have been isolated which have distinct disease reactions in the sand germinator, some being characterized by short life and others by long life.

Studies on the Diplodia disease of corn. J. R. HOLBERT, BENJAMIN KOEHLER, AND G. H. DUNGAN.

During the past five years experiments have been conducted in various parts of Illinois with yellow dent corn grown from seed infected with *Diplodia zeae* (Schw.) Lev. in comparison with corn from nearly disease-free seed. Reduced field stands and lowered vigor of surviving plants have resulted from the infected seed. Plantings made early in cool soils were reduced to 20 to 30 per cent stands from infected seed, compared with 88 to 92 per cent stands from nearly disease-free seed. Plantings with *Diplodia*-infected seed made later in warm soil high in moisture also resulted both in field stands and vigor of surviving plants being greatly reduced, while in similar plantings in warm, comparatively dry soil field stands from infected seed were reduced only to 80 to 85 per cent in comparison with 94 to 98 per cent stands from nearly disease-free seed.

Mature plants from *Diplodia*-infected seed showed less resistance to a vertical pull than those from disease-free seed.

Both open-fertilized and inbred strains of corn have been found to differ greatly in their resistance to the *Diplodia* disease.

In 1923 seed treatment for 3 hours in a 1 to 400 water solution of chlorophol increased the yield of corn from *Diplodia*-infected seed 30 per cent.

As an average of more than 40 experiments in central Illinois, neither lime nor phosphates gave a significant increase in yield with corn from *Diplodia*-infected seed.

(Cooperative investigations by the Illinois Agricultural Experiment Station, Funk Brothers Seed Company, and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Corn resistant to rust, Puccinia sorghi. E. B. MAINS, F. J. TROST, AND G. M. SMITH.

Approximately 2,800 one-, two-, three-, and four-year selfs of 15 varieties of sweet corn and 5 varieties of dent corn, which are being studied in corn root-rot investigations, also were studied in the greenhouse for their susceptibility to rust during the winter of 1922-23. Many different types of susceptibility were found, ranging from almost complete immunity and a number of different degrees and types of resistance, to more or less high degrees of susceptibility. Resistant individuals were found in the following varieties of sweet corn: Stowell's Evergreen, Early Evergreen, Narrow-Grained Evergreen, Country Gentleman, Goldenrod, Golden Bantam, Howling Mob, Early White-Cob Cory, Kendel's Early Grant, Black Mexican, and several hybrids. In the dent

corns, resistant individuals were found in the varieties, Silver King, Golden Glow, Early Yellow Dent, Johnson County White, and Darke County Mammoth. Most of the self showing resistant individuals evidently were heterozygous for this character. A few, however, were found which evidently were homozygous for resistance.

(Cooperative investigations by the Purdue University Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Wheat resistant to mildew, Erysiphe graminis. E. B. MAINS.

About 650 strains of wheat were tested in the greenhouse as to their susceptibility in the seedling stage to powdery mildew. These strains included a large number of the varieties most commonly grown in the United States, including varieties of durum, emmers, spelts, einkorn, club wheats as well as winter and spring varieties of the common bread wheats. Of the latter, Norka, Chul, Huron, Red Fern, Sonora and one strain of Michigan Amber were especially resistant, being practically immune to the mildew. Among the other wheat species Khaphi, Vernal emmer, and einkorn were the outstanding varieties.

A bacterial disease of broomcorn and sorghum. CHARLOTTE ELLIOTT AND ERWIN F. SMITH.

Bacterium andropogoni E. F. S. produces, on many varieties of sorghum and broomcorn, red lesions a few millimeters in diameter and extending as long streaks through leaf blades or sheaths. Abundant exudate dries down forming red crusts or scales. While lesions are similar in form on different varieties, color varies from deep reddish brown or purple to orange red. Lesions on a few varieties show no reddening. This color is not marginal as in many sorghum spots but continuous throughout lesions.

Isolations from broomcorn, sorgho, grain, and grass sorghums have all given the same type of organism, the pathogenicity of which has been proved by repeated inoculations and reisolations. No natural infections have been found on Sudan grass but inoculations have produced typical, dark red streaks very different from the common leaf spot of Sudan grass. The same type of lesion also has been produced artificially on a Feterita-Milo hybrid.

Sorghos appear to be most susceptible, grass sorghums most resistant and grain sorghums intermediate. There also are considerable differences in varietal resistance in each group. Attempts to extend the host range to corn and millets have not been successful.

(Cooperative investigations by the Laboratory of Plant Pathology and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Further investigations on the pasmo disease of flax. W. F. BRENTZEL.

The disease of flax caused by *Phlyctaena linicola* Speg., called "pasma" in South America, has recurred in North Dakota with considerable severity during the past season. It occurred also in South Dakota, Minnesota, Wisconsin, and Michigan. Authentic specimens from South America were examined and the fungus found identical with that in this country. In Michigan fiber flax was ruined where severely attacked and seed flax at Fargo, N. Dak., was damaged somewhat by blighting of the stems, leaves, and capsules. Large brown lesions developed on the individual plants. At

Fargo, N. Dak., these changed to an ashy gray color in the late stages of infection. The lesions often had the appearance of being pubescent due to the presence of numerous white spore-tendril or spore-horn forms in which the pycnosporos issued from the pycnidia. These spore-horns were bent or coiled and measured about 10 to 25 by 65 to 450 microns. Microscopic examination of sections through lesions have shown the pycnidia extending to the region of the bast fiber cells. In plats of fiber flax which were grown at East Landsing, Mich., by Mr. L. R. Davis, plants developed the disease most severely when the seed came from infected sources. Some varieties of both seed flax and fiber flax were more resistant than others.

(Cooperative investigations by the North Dakota Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Observations on malformed tassels of teosinte plants infected with downy mildew. J. H. CRAIGIE AND WM. H. WESTON, JR.

Of the many plants of teosinte (*Euchlaena mexicana*) heavily infected with *Sclerospora philippinensis* after inoculation as seedlings in the Philippines, several successfully matured; and some of these developed strikingly malformed tassels. These inflorescences were preserved, and their structure as now studied in comparison to that of healthy plants, shows certain points of pathologic interest. The spikelets are invariably sterile, since the stamens are usually lacking entirely, or if rarely present, have withered anthers containing few non-functional pollen grains of abnormal size, shape, and content. Moreover, the glumes and lemmas show astonishing overgrowth, often to six times normal size, and are contorted, wrinkled, and tightly enwrapped. Rarely, the normally paired florets within the spikelets show proliferation to as many as seven. Also, from the base to the tip of the rachis there is a progressive reduction in the component parts of the spikelets. The abnormalities shown by these teosinte tassels present an interesting comparison to those that have been described in the case of inflorescences of maize, wheat, rice, millet, and other grasses as a result of infection by other *Sclerosporas*.

Fusarium culmorum in Oregon, its varieties and strains that cause disease of cereals and grasses. JESSIE P. ROSE.

Isolation of *Fusarium culmorum* and its strains from cereals grown in different sections of Oregon, inoculation experiments, study of cultures upon different media at the Oregon State Experiment Station (1918-21), and in Wisconsin (1921-23), together with studies and determinations made by C. D. Sherbakoff show; that there are present in Oregon, *Fusarium culmorum*, *F. culmorum* var. *leteius*, and at least two other distinct varieties and one strain, (descriptions not published); that although these Fusaria have the color characters of *F. culmorum* and *F. culmorum* var. *leteius*, there are certain morphological and physiological characters and host relationships that differentiate them; that all of these Fusaria will cause disease of Triticum, but in varying degrees; that *Fusarium culmorum* and closely allied forms cause disease of Triticum and Avena, but certain strains seem to attack Avena more severely; that the variety, *F. culmorum* var. *leteius* will cause disease of Triticum, Avena, Zea mays, Secale, Hordeum, and grasses belonging to the genera Agropyron, Arrhenatherum, Avena, Elymus, Hordeum and Lolium, but Triticum and Avena seem to be the preferred host genera. These studies show that *Fusarium culmorum* may not only contain distinct varieties, but suggest that it may also contain distinct biological strains.

Fusarium culmorum var. *leteius*, a cause of disease in cereals and grasses. JESSIE P. ROSE.

In cereal investigations at the Oregon State Experiment Station, during 1918-21, *Fusarium culmorum* var. *leteius* Sherbakoff, was isolated from diseased plants of wheat, corn, oats, barley, Italian rye grass, from wheat seed rarely, and from the soil of infested fields, which represented the principal sections of Oregon. In extensive inoculation experiments conducted in the laboratory, greenhouse, and field, this *Fusarium* was found to cause blighting of wheat seedlings, diseased conditions of mature plants, a reduction in stand, and decreased yield.

Controlled temperature and moisture studies in the greenhouse, and field-temperature studies in Wisconsin during 1921-23 show that in addition to causing diseased conditions of spring and winter wheats, this *Fusarium* will cause seedling blight and diseased conditions of mature plants of barley, oats, rye and grasses belonging to the genera, *Agropyron*, *Arrhenatherum*, *Avena*, *Elymus*, *Hordeum* and *Lolium*. The percentage of blighting and severity of the disease depending upon the condition of the seed and environmental factors, particularly temperature and moisture. In controlled inoculation experiments, it was found that this *Fusarium* will cause severe scab of wheat.

Experiments with dusting and spraying for the control of tobacco wildfire in seed-beds.
JAMES JOHNSON.

The extent of the damage caused by wildfire in the field is largely dependent upon the weather conditions prevailing. According to observation and experiments a small percentage of infection on the seedlings may eventually cause a comparatively heavy field infection. The application of copper-lime dusts and Bordeaux mixture sprays is not believed to reduce plant-bed infection sufficiently in most cases to overcome the damage which may result from the transplanting of slightly diseased plants. Our experience has not gone far enough, however, to imply that dusting or spraying may not be beneficial under certain conditions.

The effectiveness of copper fungicides against the wildfire bacteria does not seem to be due to the copper they contain. Certain calcium compounds seem to be equally effective in preventing wildfire infection. It seems likely that dusts and sprays are in part beneficial because of the mechanical barrier they offer to infection.

Disinfection of tobacco seed against wildfire. JAMES JOHNSON AND H. F. MURWIN.

Formalin and corrosive sublimate treatments have been recommended for disinfecting tobacco seed against the wildfire organism (*Bacterium tabacum*). Both of these treatments have proven to be injurious to germination under certain conditions. Corrosive sublimate treatment results in practically complete prevention of germination of tobacco seed where sprouting before sowing is practiced, although no appreciable injury occurs where seed is sown directly in the soil or is tested for germination on filter paper. Corrosive sublimate cannot be recommended, therefore, in districts where growers sprout their seed before sowing.

Modifications of the above methods, as well as several other methods, have been tried without giving the desired results. Silver nitrate treatment (1-1000) for fifteen minutes, however, gave better disinfection than formalin treatment and equally as good disinfection as corrosive sublimate. No injury to the seed follows silver nitrate disinfection by any method of sprouting practiced by growers. Doubling the strength or

time of treatment or omitting rinsing in water after treatment produced no injury. Silver nitrate seems therefore to be an ideal disinfecting agent for tobacco seed.

Angular leaf-spot and wildfire infection of tobacco plant beds by spitting. W. D. VALLEAU
AND CHARLES HUBBARD.

Angular leaf-spot and wildfire infection usually did not occur in tobacco plant beds in Kentucky until after weeding. Angular leaf-spot was very prevalent the past spring, being found in over 90 per cent of the plant beds examined. Chewing the natural leaf from the previous year's crop is a habit common to about 90 per cent of tobacco growers in Kentucky. Various investigators have shown that the organisms causing these two diseases are capable of living over winter in the cured leaves. Experiments conducted during September 1923 in tobacco plant beds located outside have demonstrated that wildfire and angular leaf-spot may be introduced into the plant bed by chewing leaves infected with one or the other of these diseases and spitting the material on the young plants in the bed. The leaves used were air-cured and from the current season's crop. Seed treatment, supplemented by the usual sanitary precautions, has not resulted in control under farm conditions. It is believed that chewing tobacco is the chief source of plant bed infection in Kentucky, and that attention to this source, supplemented by seed-treatment and proper selection of seed-bed site to prevent the introduction of tobacco trash will result in complete control in the plant bed. It is possible that the distribution of commercial tobacco may explain the rapid world distribution of wildfire since its discovery in 1917.

Progress report upon the resistance of commercial strains of tobacco to root-rot. C. R.
ORTON AND OTTO OLSON

Thirteen distinct strains of Pennsylvania Broadleaf and Havana types of tobacco have been tested for their reaction to root-rot, attributed to *Thielavia basicola*, on severely infested soil under field conditions during the past four years. Three of these strains, Hibshman, Leaman and Olson which are of the best commercial types have been found to be highly resistant to this disease as well as two other strains which are of less commercial importance in Pennsylvania. Attention is called to a unique plan of field tests by means of which the variable factors of soil environment are reduced to the least error.

Progress report on Phytophthora-resistant tobacco. W. B. TISDALE.

During the last two years black shank, caused by *Phytophthora mcotianae* Van Breda de Haan, has been recognized as the most serious disease of tobacco in the Florida-Georgia district. The causal organism inhabits the soil and persists at least five years after infested land has been abandoned for tobacco culture. It attacks the roots and lower portions of stems and lower leaves of tobacco in any stage of development. The disease may cause a 50 per cent reduction in yield the first year it appears in a field, depending upon the variety of tobacco and its stage of development when first attacked. Connecticut Round Tip appears to be completely susceptible to the disease, while Big Cuba, the common Florida variety, is more resistant.

In 1922 seed was saved from several healthy Big Cuba plants in badly diseased fields. Progeny of these mother plants were tested on infested soil in 1923 and a few of them showed a high percentage of resistance to black shank, as shown in the following table:

Strain	No. of plants	Diseased per cent	Living per cent	Yield per Acre pounds
E-22-2	431	26	95	900
P-22-3	112	19	95	960
E-22-14	400	24	93	1,080
Big Cuba, check	520	82	77	480

Studies of anthracnose infection in cotton seed. C. A. LUDWIG.

Cotton seed which is badly infested with the anthracnose fungus and spores gradually becomes clean after being stored for a considerable time. Thus it is perfectly safe to use it for planting the third spring after gathering if stored under laboratory conditions and is practically safe the second spring. The greatest reduction in infection occurs during the autumn when the seed is about a year old. Seed kept in a moist atmosphere cleared up more rapidly than other seed, but became musty and ceased to germinate. Seed stored in a uniformly very dry atmosphere remained very heavily infected for over two years. Alternating between a very moist and a very dry atmosphere reduced the infection somewhat more rapidly than ordinary storage and did not permit a great amount of mustiness to develop. Storage in laboratory conditions appeared to be slightly more favorable to the dying out of the fungus than storing under an open shed in conditions comparable to those usually available to farmers. Preliminary heating or drying by ordinary methods did not help appreciably. Delinting with sulphuric acid, followed by sterilizing with mercuric chloride reduced infection very much but did not eliminate it.

Chestnut blight in Europe (Endothia parasitica (Murr.) A. & A.). HAVEN METCALF.

The occurrence of chestnut blight at Bruges, Belgium, is reported. It is believed that this is the first report of this disease in Europe. In London a chestnut staging-pole was observed with a blight canker on it, but the fungus was dead. The theory is advanced that the chestnut blight may have been taken to Europe from America on chestnut poles or other chestnut timber during the war.

Observations on the Douglas fir canker (Phomopsis pseudotsugae Wilson) in Great Britain. HAVEN METCALF.

During the last twenty years great numbers of American Douglas Fir (*Pseudotsuga taxifolia* (Poir.) Britt.) have been planted in Great Britain, particularly in Scotland; and especially since the war, which gave a great stimulus to reforestation. The tree is planted mostly in pure stands. In many places the Douglas fir canker has assumed a serious aspect. It was seen by the writer at various points from Exeter, England, north to Loch Awe, Scotland, and probably occurs throughout the British Isles wherever Douglas Fir is planted. At least until its origin is determined, this disease must be regarded as a dangerous potential enemy of the Douglas Fir forests of America. It has not yet been found in America nor on the continent of Europe.

Wind dissemination of asciospores of Cronartium ribicola Fischer. L. H. PENNINGTON.

Field studies upon the white pine blister rust were carried on for the U. S. Department of Agriculture during the seasons of 1922 and 1923 in the Pacific Northwest. These studies indicate that the rust in this region originated from infected *Pinus strobus* which was imported in 1910 from France into Vancouver, British Columbia.

The rust has spread widely. It has been found upon *Ribes* at the north 110 miles beyond the limits of white pine, at the south to the mouth of the Columbia River, and at the east across the Dry Belt upon both pines and *Ribes* from 150 to 200 miles from infected pines in the Coast region. This Dry Belt, 150 miles wide with no white pines, separates the eastern and western belts of white pine in British Columbia.

It has become increasingly evident that the extensive distribution of the rust has been caused by wind-born aeciospores. At long distances from the source of aeciospores, infection has been found most frequently upon the cultivated black currant, *Ribes nigrum*. This emphasizes the fact that in the Northwest as well as in other regions *Ribes nigrum* is a most dangerous host for the spread and establishment of white pine blister rust.

Survey of blister rust infection on pines at Kittery Point, Me., and the effect of Ribes eradication in controlling the disease. G. B. POSEY AND F. R. FORD.

In 1916 the white pine blister rust (*Cronartium ribicola* Fischer) was found to be epidemic on native white pines (*Pinus strobus* L.) at Kittery Point, Maine. From 1917 to 1921 field studies were made upon the epidemiology and local control of the disease on this severely infested area. The principal damage occurred on pines growing within 900 feet of a patch of cultivated black currants (*Ribes nigrum* L.). Local storm winds influenced the direction of spread of the disease and its concentration on pines varied with the size and dominance of the trees and the density of the stand. Complete eradication of *Ribes* in 1917 prevented any further infection on the pines and in five years has permitted natural restocking with healthy pine seedlings at the rate of 242 trees per acre.

Controlling white pine blister rust in the Northeastern States. E. C. FILLER.

Practical control of the white pine blister rust is being accomplished in the Northeastern States by systematically eradicating wild and cultivated *Ribes* spp., growing within infecting range of white pine stands. Under average field conditions this distance does not exceed 900 feet. Land owners or crews of laborers can do the control work effectively under trained supervision and leadership. In 1917 the U. S. Department of Agriculture in cooperation with the infested states initiated a general control program for preventing serious damage to the white pine crop in infested regions. Since then *Ribes* have been destroyed on approximately two and one half million acres of land growing white pine. Efficiency checks on areas worked show that more than 95 per cent of the *Ribes* were found and eradicated. The average per acre cost of this work has been reduced from 72 cents in 1918 to approximately 20 cents in 1923. Recent surveys of control areas worked several years previously show that *Ribes* eradication has been effective in preventing further commercial damage to the pines.

Hypoxylon poplar canker. ALFRED POVAH.

(Abstract in *Phytopath.* 12: 59. 1922.)

Wound healing of mesophytic leaves. ROBERT B. WYLIE.

Numerous layers of mesophyll cells, which collapse and die when exposed by wounding, constitute the initial protection to the cut edge of the leaf. This false cicatrice is sup-

plemented in *Vitis vulpina* by the infolding of the epidermal layers over the wounded edge, and in *Rhus glabra* by the latex poured out in the region of larger veins. Mitoses begin in two or three days but the healing process is not completed in these leaves for nearly two weeks. The cicatrice consists of several layers of cells which are tightly fitted together building a cork-like tissue across the wounded edge of the leaf. The walls of these cells are considerably thickened, and the cells have modified content. Lignin may be demonstrated within 24 hours after wounding, and it persists indefinitely in the cicatrice. All cell layers of the normal leaf take part in the formation of the cicatrice, but the epidermal cells of such mesophytic leaves seem to divide but once while in some xerophytes a single epidermal cell may give rise to many cells of the cicatrice. Since infection so seldom follows leaf wounds it seems that both the temporary and the permanent cicatrice are efficient in protecting the leaf from fungi.

Insect transmission of aster yellows. L. O. KUNKEL.

During the time of most rapid spread of the aster yellows disease in experimental plots at Yonkers, N. Y. the tarnished plant bug *Lygus pratensis* L. and the leaf-hoppers *Cicadula sex-notata* Fall. and *Empoasca unicolor* Gill. were present in abundance. A third leaf-hopper *Graphocephala coccinea* Forst. was present but rather rare. Aphids were occasionally observed but were never abundant.

Experiments in which the tarnished plant bug and the leaf-hoppers *Empoasca unicolor* and *Graphocephala coccinea* were transferred from diseased plants to healthy young plants in insect-proof cages gave in all cases negative results and suggest that these insects do not spread the disease. Similar experiments in which *Cicadula sex-notata* was used, show that this leaf-hopper readily transmits aster yellows. By using a non-infected culture it was shown that the insect is capable of transmitting yellows only after feeding on diseased plants. It is believed that *Cicadula sex-notata* is responsible for most, if not all, of the spread of aster yellows in the vicinity of New York City.

A flagellate infection of milkweeds in Maryland. FRANCIS O. HOLMES.

Typical herpetomonad flagellates occur in the latex of plants of *Asclepias syriaca* Linnaeus in the vicinity of Baltimore, Maryland. The infections are very heavy; in the freshly drawn latex active movement is easily observed. Dividing forms may also be seen.

In size and morphological characteristics the organism agrees with the description of *Leptomonas Ebnassiani* Migone, a small form, found in 1916 in Paraguay. This name should now be *Herpetomonas elmassiani* for the two genera were united under that name by Butschli (1884). Near Baltimore *Oncopeltus fasciatus* (Dall.), a common red and black hemipterous insect frequenting the infected colonies of milkweed, is under suspicion as the transmitter, since the flagellates in its intestinal contents closely resemble those in the plants.

In infected milkweeds the flagellates reach all parts except the roots and seeds. The plants are yellowed and the smaller pods are frequently shrivelled. Whether or not this is due to the flagellosis requires further investigation. Pictures of the flagellates drawn to scale are presented herewith.

(Joint contribution from the laboratories of the Thompson Institute for Plant Research and of the Department of Medical Zoology, School of Hygiene, Johns Hopkins University.)

Mosaic cross-inoculation studies. OTTO H. ELMER.

Mosaic of plants is transmissible between hosts belonging to distinct orders and families. Such infection has been secured under controlled conditions by artificial inoculations and through the agency of insects. Successful infections of mosaic have been secured to *Nicotiana tabacum* from the following hosts:

Cucumis sativus, *Cucurbita moschata*, *Phaseolus vulgaris*, *Abutilon theophrasti*, *Zinnia elegans*, *Calendula officinalis*, *Stokesia laevis*, *Asclepias syriaca*, *Rubus* sp. (Red raspberry), *Martynia louisiana*, *Euphorbia preslii*, *Aquilegia canadensis*, *Apium graveolens* and *Saccharum officinarum*; to *Lycopersicum esculentum* from: *Abutilon theophrasti*, *Zinnia elegans*, *Calendula officinalis*, *Asclepias syriaca*, *Nepeta cataria*, *Martynia louisiana*, *Apium graveolens* and *Saccharum officinarum*; to *Vigna sinensis* and *Soja max* from *Cucurbita moschata*, to *Cucurbita moschata* from *Lycopersicum esculentum*; to *Vigna sinensis* from *Solanum melongena*; and to *Martynia louisiana* from *Nicotiana tabacum*.

With bean and sugar cane mosaic, artificial infections to tobacco and to tomato have been secured only when inoculations were made with mosaic tissue macerated in a solution of acetone. This chemical has not been an aid in other crosses.

Artificial infections are generally more difficult and the incubation period is usually longer in cross-inoculations between families than is the case within the family. For successful artificial infection between families it is necessary that a vigorous growing condition is present not only in the inoculated plants but also in the plant from which the inoculum is taken.

Transfer of mosaic disease from red to black raspberries. RAYMOND B. WILCOX AND FLOYD F. SMITH.

By placing aphids (*Amphorophora rubi* Kalt.) from healthy raspberry plants upon leaves of King red raspberries affected with mosaic disease, allowing them to feed for a few days, then transferring them to young tip leaves of healthy Kansas black raspberries, symptoms have been induced in the latter which have frequently been noted in the field.

Tips of the black raspberries wilt and usually die to a distance of from one to three inches from the terminal bud; the green color of the next leaf fades, beginning at the base, and leaves a somewhat mottled appearance; this symptom then appears in other leaves progressively down the stem; growth of the plant is retarded.

Black raspberry plants upon which were placed aphids of the same species from healthy raspberries remained apparently healthy. The symptoms were not induced by aphids of other species.

These experiments have been performed both in the field and greenhouse.

Cytological studies on tobacco mosaic. T. E. RAWLINS AND JAMES JOHNSON.

Cytological studies on tobacco mosaic, using Haidenhain's iron-alum haematoxylin stain with best results, demonstrated the occurrence of at least three distinct abnormal cell inclusions in chlorotic tissue. Among the first abnormalities to appear after inoculation is a mass of yellow-staining striate material which radiates from the nucleus. In young leaves the cytoplasm of the same cells usually contain one or two small black staining bodies about the size of the nucleoles. In some of the cells of older leaves as many as twelve bodies of this same type were observed. Vacuolate bodies varying in size from those just visible to slightly larger than the nucleus occur adjacent to the nu-

cleus at first, but appear to increase in size and become detached from it later. The early stages of the vacuolate bodies found in the glandular trichomes often contain a black staining central granule.

With the exception of the type in which a single cell contains numerous small, black-staining bodies, all of the above types have been found in dividing cells. The body apparently passes to one of the daughter cells during the division.

Temperatures which inhibit the development of mottling also inhibit the development of these bodies.

No conclusion has been reached as to whether these abnormal bodies are concerned with the cause or the result of the mosaic disease.

Physalis and cucurbit mosaic intertransmissible. M. N. WALKER.

Inoculations during the past year indicate that the mosaic diseases of *physalis* and cucumber are intertransmissible. An annual species of cultivated ground-cherry (*Physalis pubescens* ?) was used in these inoculations. The occurrence of a considerable number of mosaic wild perennial *physalis* plants, (*P. heterophylla* and *P. subglabrata*) in the vicinity of mosaic infected cucumber fields indicates that *physalis* is concerned in the overwintering of cucurbit mosaic. Preliminary inoculations from mosaic plants of these species have borne out this belief. The favorable results obtained by the eradication of *physalis* in experiments on the control of cucurbit mosaic also indicate that it is an important source of infection to the cucumber although these results were somewhat complicated by abnormal seasonal conditions. The cultivated *physalis* has also been found susceptible to pokeweed mosaic and has served as an intermediate host in inoculations from mosaic tomatoes to the cucumber. *Physalis* has proven especially valuable in the latter experiments since it is a host plant for aphids from both the cucumber and tomato. A complete report of this work will appear at a later date.

Experiments on the control of cucurbit mosaic. S. P. DOOLITTLE AND M. N. WALKER.

Continued investigations indicate that cucurbit mosaic overwinters on the pokeweed, *Phytolacca decandra* and on *Physalis* spp. in addition to the milkweed, *Asclepias syriaca*, and wild cucumber, *Micrampelis (Echinocystis) lobata*. Their importance varies with the locality. All excepting the pokeweed are found in Wisconsin and northern Illinois. Mosaic pokeweeds occur in Michigan and Indiana and appear to be the chief source of infection in southern Illinois. In field experiments on the control of mosaic through the eradication of wild host plants at Rockland, Wis., during 1923, mosaic *Physalis* appeared to be the chief source of infection. These experiments included ten fields which in preceding years had been from 30 to 100 per cent mosaic. During 1923, nine of these fields averaged less than one per cent mosaic on September 1. The remaining field was infected early in the season, despite eradication, and showed 70 per cent mosaic, indicating that seasonal conditions were not such as to prevent the development of the disease. At Madison, Wis., the milkweed appeared to be the source of infection in a field which has been in use for experimental work for the past six years and has been 100 per cent mosaic each season. Following eradication, this field showed only 6 per cent of mosaic on September 1, although surrounding fields suffered severely. Preliminary experiments in southern Illinois indicated that eradication of the pokeweed also gave apparent control of the disease.

The mosaic disease of Nicotiana glutinosum not distinct from tobacco mosaic. M. N. WALKER.

The inoculation of healthy plants of *Nicotiana glutinosum*, the *N. viscosum* of Allard's paper, "A specific mosaic disease of *Nicotiana viscosum*," with tobacco mosaic resulted in infection in a large number of cases. Controls remained healthy. It was found also that the mosaic disease of *N. glutinosum* as occurring at Madison, Wis., is transmissible to tobacco. Toward the end of the growing season it was found that infection was less readily secured or that the symptoms were so masked on *N. glutinosum* plants as to prevent accurate diagnosis. This fact may account for the negative results given in the paper mentioned. Although Allard's results suggest the existence of two types of mosaic disease within the single genus *Nicotiana*, the present work indicates the probability of the existence of but a single type. A full report of these results will appear in a later paper.

The relation of Chenopodium murale to curly-top of the sugar beet. EUBANKS CARSONER AND C. F. STAHL.

Many of the beet leafhoppers which come into the beet fields in spring are non-viriferous. *Chenopodium murale* is one of this insects' winter host plants. Inoculations have shown that this plant is very resistant to curly-top. Tests with nymphs reared on this plant from viriferous parents have indicated that usually the virus of curly-top is so attenuated by its passage through this resistant plant that it subsequently fails to cause the disease or else produces only mild cases. It seems probable that the non-viriferous leafhoppers which enter the beet fields in spring come from *Chenopodium murale* or plants comparable to it in relation to curly-top. Studies are in progress to determine whether or not the attenuated virus can be reactivated.

Experiments with inoculated sulphur for scab control. JULIAN G. LEACH AND R. C. ROSE.

Experiments have been conducted for two years at various points in Minnesota on a wide variety of soil types, including peat. The results obtained were very variable. In a few cases an appreciable reduction in the amount of scab was obtained but in the majority of cases little or no control could be detected. In many places the application of inoculated sulphur resulted in a decreased yield without any appreciable reduction in the amount of scab. The particular type of soil on which the sulphur is applied appears to have a great deal to do with the effectiveness of the treatment.

Spraying vs. dusting for potatoes. JULIAN G. LEACH.

Comparative spraying and dusting experiments were conducted co-operatively by the Sections of Plant Pathology and Entomology of the University of Minnesota during 1922 and 1923, in which the following sprays and dusts were used.

Liquid Bordeaux Mixture (4-4-50) (1922 and 1923).

Liquid Bordeaux Mixture and Black Leaf 40 (1922 and 1923).

Liquid Bordeaux Mixture and Kayso (1923).

Liquid Bordeaux Mixture and Sodium Silicate (1923).

Dosch Copper Calcium Arsenate Dust (1922 and 1923).

Dosch Copper Calcium Arsenate and Nicotine Dust (1922 and 1923).

Nicotine Dust (1922).

Niagara Nicotine Dust (1923).

The experiments were conducted on 1/10 or 1/12 acre replicated plots at the University Farm and were duplicated on Bliss Triumph and Green Mountain potatoes. All sprays were applied with a Friend power sprayer, using three nozzles per row, and dusting was done with a Niagara power duster. All plots were sprayed or dusted four times.

The average increase in yield per acre over the check plots (sprayed or dusted with arsenates only) was 57 bushels (34 per cent) and 20 bushels (12 per cent) for the sprayed and dusted plots respectively in 1922. In 1923 it was 19 bushels (9 per cent) and 6.5 bushels (3 per cent). This year the leafhoppers were not as numerous as in 1922 and appeared about one month later.

Loss of strength of mercuric chloride solutions used for treating potatoes. R. P. WHITE.

It has been known for some time that mercuric chloride solutions used for treating seed potatoes for scab and *Rhizoctonia* lose their strength with use. In the experiments recorded here the strength of the original solution was 1-1000. After using this solution four times with whole seed, the strength of the solution was found to be 57.4 per cent of the original strength. When used four times with cut seed, the strength of the solution was found to be 12.5 per cent of the original strength. The area exposed to the solution by the cut seed was approximately twice that exposed by the uncut seed, by actual measurement. The strength of the solution decreased approximately twice as rapidly. In addition to the increase in surface of the potato tuber, there is also a significant increase due to the liberation of starch grains from the cut cells. The surfaces of these grains act as adsorbers of mercury ions and tend to reduce the strength of the solution. Weakening of mercuric chloride solutions used for treating seed potatoes is proportional to the surfaces exposed, that may act as adsorbers of mercury ions.

Potato seed treatment tests in Manitoba. G. R. BISBY.

Four years' tests have shown that black scurf begins to develop on potato tubers at Winnipeg ordinarily during August, and accumulates in increasing amounts through September. There is a variation from year to year in the amount of scurf at a given date, but digging as soon as the potatoes are mature lessens the percentage of black scurf. Neither corrosive sublimate, copper sulphate, copper carbonate, nor semesan exerted any noticeable "residual effect" in preventing the development of sclerotia arising from the fungus in the soil. Semesan may increase the yield somewhat. Both inoculated and non-inoculated sulphur reduced scab, but did not lessen black scurf, and sulphur was not found to be practicable. The potato scab organism may be very abundant in virgin Red River soil. The various seed treatments nevertheless gave better results with scab than with black scurf.

Some factors influencing the development of potato scab. G. B. SANFORD.

Experiments have been made to determine the influence of soil moisture, soil temperature, soil reaction, and the age of the tubers on the development of common scab. Two types of soil were used: a fine textured non-organic sandy loam with a reaction approximately pH 7.2, and a black sandy loam high in humus content with a reaction of approximately pH 6.2. Under controlled moisture and temperature a maximum of scab developed in dry soils at 14° C., 17° C., and 22° C. Soil moisture has appeared to exert a much greater effect on scab development than the temperatures between 14° C.

and 22° C. In all cases the most scab developed in the drier soils, while the most moist soils partially or completely inhibited scab development. Dry soils constantly were slightly more acid than the same soils moist. Tubers appeared most susceptible to infection before they reached one-half inch in diameter. With the Cobbler variety, maximum infection occurred between forty and fifty days after planting. The above facts should be taken into consideration when interpreting results of experiments on scab control.

Further results in the inheritance of immunity to potato wart. FREEMAN WEISS AND C. R. ORTON.

Further tests have been made of first generation hybrid potatoes and a few plants in the F₂ to determine their reaction to wart disease. Owing to the heterozygous constitution of potato varieties segregation is obtained in the F₁. In a few cases families of from 10 to 20 individuals derived from a single cross have been grown, each seedling being multiplied vegetatively so that 25 or more plants have been tested through 1 to 4 years. Grouping the crosses into the following classes gives these results:

	Immune	Susceptible
Immune × immune or × self	12	0
Immune × susceptible	35	25
	} 38	} 28
Susceptible × immune		
Susceptible × susceptible or × self	3	3
	1	89

Immunity is dominant. Reciprocal crosses of immune and susceptible parents react similarly. The small excess of immunes in the combined crosses of this class points to the simultaneous action of 2 factors producing immunity, with a ratio of 9 to 7 as the expectancy. It is possible that only a single factor is involved and that the immune types are heterozygous so that equality of immune and susceptible progeny should be expected, but the individual families usually show an excess of immunes, and none have given ratios agreeing with expectancy if 2 independent factors are concerned as found in England by Salaman and Lesley. The Rural New Yorker and its synonyms behave as homozygous recessives.

Root diseases of sugar cane in Porto Rico. MEL. T. COOK.

The root diseases of sugar cane in Porto Rico have been considered of secondary importance but the numerous reports and field studies of the past few months lead the writer to believe that these diseases are of major importance. These diseases are found in all types of soils. The infected canes are dwarfed and usually show leaf spot symptoms which frequently mislead the field observers. The presence of the cane borer and the white grub also lead to confusion and many growers attribute the entire trouble to these agencies. Careful field studies show the roots to be numerous and decayed and the production of numerous adventitious roots from the nodes, sometimes as much as 20 inches above the ground. Laboratory studies of weak and dead canes demonstrated the presence of *Colletotrichum falcatum*. This organism was also found in some of the slightly infected roots. No definite conclusions as to the primary causes have been reached.

First progress report on the study of apple scab under Ohio conditions. W. G. STOVER AND H. W. JOHNSON.

During the past season, several phases of the apple scab problem were studied on Rome Beauty trees in a commercial orchard near Columbus. The trees were dormant until the middle of April. The buds reached the pink stage about May 4. The first observed discharge of ascospores of *Venturia inaequalis* occurred on April 4 and the last on June 8. The period of heaviest discharge was May 8-21.

The season was favorable for scab development. On unsprayed trees 86 per cent of the fruit was scabbed. The disease was first observed on the leaves on May 22, and on the fruit on June 4.

Liquid lime sulfur and Bordeaux mixture gave satisfactory control. Foliage injury occurred where Bordeaux was applied after bloom. Neither sulfur dust nor copper-arsenic dust gave commercial control. Fair control was secured where the trees were sprayed with lime sulfur before bloom and dusted with sulfur after bloom. Lime sulfur followed by copper-arsenic dust failed to give commercial control.

The pink spray was the most important single application in the schedule this year, while the prepink was of practically no value. Weather conditions were not favorable for infection before the pink spray.

Studies on apple blotch in Ohio. W. G. STOVER AND CURTIS MAY.

Examination of Smith Cider twigs with blotch cankers, collected near Columbus, showed that viable spores were present in considerable number from the middle of April until the middle of August. Spores were found in pycnidia in diseased fruits from July 9 to August 29.

Bagging experiments showed that the first infections occurred June 4-8, sixteen days after the petal fall spray. Infection continued until after July 27, when the last of the bagged fruits were exposed. The disease was first observed on the fruit on June 29, three weeks after the earliest infection period as determined by the bagging experiments.

Other studies indicate that many, perhaps most, of the twig cankers originate from lesions on the petioles, as previously reported by others.

Spraying with Bordeaux 3-6-50 (hydrated lime) at petal fall and 2, 4, 6 and 10 weeks later gave an average of 90 per cent blotch-free fruit while 60 per cent of the fruit on unsprayed trees was blotched. At each application one tree was left unsprayed. Under the conditions of this experiment no one application was more effective than the others.

Three little known diseases of strawberries. C. D. SHERBAKOFF.

(1) Lilac softrot of berries and (2) brown hardrot of berries were common and destructive during the past season in Tennessee. Isolations from interior of diseased tissues gave a *Pythium* from the softrot and a *Rhizoctonia* from hardrot. The first disease affects half-ripe and ripe berries. In the latter case the color of the rot is lilac. The hardrot affects the berry in all stages of its development; the growth in diseased portions is arrested, thus producing a more or less one sided berry. (3) Blackrot, a disease of very wide occurrence in Alabama and Tennessee and apparently farther north, has assumed proportions of a considerable economic importance in certain districts; it is manifested by blackening of the roots from the crown downward. Many

of the affected plants begin to die shortly before the time of maturity of the berries; however, most of the plants survive through the season but with most of the leaves dead; on many occasions the same fungus was isolated in pure cultures from the diseased roots; the fungus so far remains sterile and is characterized by the production of dark "plate" in culture.

Powdery mildew of raspberries. JULIAN G. LEACH AND J. L. SEAL.

A powdery mildew affecting both red and black raspberries was very prevalent in Minnesota in 1923. It does not appear to be very destructive although in cases of heavy infection of young plants or young shoots a distinct dwarfing may result. Affected leaves are usually more or less curled and wrinkled and are mottled with pale green to yellow blotches. Affected plants show considerable resemblance to mosaic or leaf curl, depending upon the degree of infection. The mycelium is confined almost entirely to the under surface of the leaves. On account of the normal white pubescence of the leaves, the mildew is often not recognized.

In view of the quarantines against mosaic, leaf curl, and blue stem of raspberries recently enacted by several states, which will necessitate extensive inspection and roguing, the above observations should be given publicity. This is particularly true since much of the inspection and roguing will probably be done by men not especially trained in pathology.

Spray injury. H. C. YOUNG AND R. C. WALTON.

During the past summer there was an unusual amount of injury to foliage and fruit from spray materials. A study was made of the various types of injury to apple, peach and pears. It was found that the injury resulting from the sulphur sprays could be grouped under 5 types, namely, edge burn, leaf scald and goose neck with lime sulphur, and injury following scab, and yellow leaf with almost all types of sulphur sprays. The injury from copper sprays was as serious on the leaves as any of the sulphur sprays and in addition caused russetting on 90 per cent of the Greening apples. Likewise, experiments were conducted with Barium tetrachloride and calcium arsenate. The exact cause of the injury in any case was not determined except that weather conditions had a decided influence on the amount of injury. This paper is intended as a progress report, and the physiological and chemical phases are being continued. The investigation was carried on in New York and Pennsylvania under the auspices of the Crop Protection Institute.

Colloidal sulphur as a spray material. H. C. YOUNG.

This paper is simply a report of progress. Experiments were conducted to test out the fungicidal value of colloidal and precipitated sulphur using the same methods of preparation as that reported in the Annals of the Missouri Botanical Garden, 1922. The tests were made in five states, namely, New York, Pennsylvania, Virginia, Illinois and Michigan. The materials were prepared at the Geneva Station and sent to the cooperating stations.

In all the states both mixtures controlled scab almost completely. There was no injury to foliage except with one application of colloidal sulphur in New York State. With the precipitated sulphur there was no injury whatever, and the foliage looked the best of any sprayed or unsprayed plots.

Both types of sulphur were applied to peaches, grapes, cherries and pears. The colloidal sulphur injured the leaves slightly in some cases, but the precipitated injured in no case. The most succulent foliage of peaches and grapes showed no injury with precipitated sulphur. It was impossible to purify the colloidal sulphur mixture so as to free it of soluble materials with the equipment at hand which, undoubtedly, was the factor in producing injury.

A number of similar compounds are now being produced commercially. This work was headquartered at the N. Y. Agricultural Experiment Station and done under the auspices of the Crop Protection Institute.

Seed transmission of root-knot nematode resistance in the peach. J. A. McCLINTOCK.

During the seasons of 1922 and 1923 second generation seedlings, from peach trees, which had proven resistant to root-knot, were grown in nematode infested soil. Examination at the close of each growing season showed that a large per cent of these second generation seedlings were free from root-knot. Peach seedlings of the Georgia Belle variety, and also tomato and lettuce plants showed abundant root-knots when grown in the same soil.

These results indicate that nematode resistant peaches transmit this factor of resistance to a high degree through the seed during the first two generations. This offers a solution of the nematode problem in peaches, through the use of resistant seedlings as stocks upon which to bud standard varieties of peaches.

A more detailed account of this work has been submitted for publication.

Present status of stem and bulb nematode in America. G. H. GODFREY.

The stem and bulb infesting nematode, *Tylenchus dipsaci*, is increasing in importance in America. During the past year it has spread abundantly in areas where it has been under observation. Furthermore, it has been found to be much more widespread than was at first supposed. In the susceptible crops that are adapted to rotations, such as clover, bulbs, and strawberries, reasonable control can be secured as a rule without great economic loss. In the case of alfalfa, with which rotations are not so practicable, however, the disease is capable of becoming more serious. These nematodes have been grouped according to host preference into so-called biologic strains. Under favorable conditions for infection, such as those existing in a cool but humid locality, certain strains have shown their ability to reach out beyond these bounds. Potato, onion, pea, buckwheat, turnip and other crops may be infested by nematodes from one or more of the primary hosts. The possibility of gradual adaptation to new hosts is indicated. Nematode infested dandelions (*Taraxacum officinale*) were found in western New York, in Ontario, Canada, and at Boston, Mass. Their wide spread has been explained, in part at least, by the finding of nematodes actually within the seeds. They may thus be carried by the wind and established in a new locality.

Relative susceptibility of red clover to anthracnose and mildew. JOHN MONTEITH, JR.

A number of plantings have been made in various States under the direction of Dr. A. J. Pieters to compare imported red clover seed with home grown seed from various sources. On these plots and in greenhouse tests it has been observed that there is a striking difference in resistance to certain diseases. In sections where anthracnose has been common the plots planted with seed of Italian origin have been practically killed

out. Plants from seed grown in Italy or other countries of southern Europe have appeared to be most susceptible to injury by anthracnose (*Colletotrichum trifolii* and *Gloeosporium caulivorum*). Some strains of home grown red clovers are the most resistant of any lots tried thus far. This greater resistance to the disease does not apply to all American clovers for some lots appear as susceptible as certain of the imported lots of seed. These plots also showed different degrees of susceptibility to powdery mildew in the reverse order to the susceptibility to anthracnose. The Italian clovers which are most susceptible to anthracnose are most resistant to mildew while certain of our American strains which are most resistant to anthracnose are most susceptible to powdery mildew.

An investigation of clover root rot. W. J. YOUNG.

A large number of cultures of *Fusaria* were isolated from the roots of clover plants killed by root rot. Comparative study reduced cultures to about twelve strains which were used for inoculating clover plants in the greenhouse. Some strains proved harmless, others gave rise to definite cankers on the tap root but none were able to kill the clover plants outright.

Conclusion: Some of these *Fusaria* are weak parasites which are able to infect clover but require the cooperation of other deleterious agencies to induce fatal results.

The range of toleration of hydrogen-ion concentration exhibited by Fusarium tracheophilum in culture. A. J. MIX AND DOROTHY LEE VAUGHN

A strain of *Fusarium tracheophilum* from cowpea was grown on potato dextrose agar and in potato dextrose broth to which varying amounts of lactic acid or of NaOH were added. Growth occurred on the agar at all concentrations tried between pH 2.6 and pH 11.8. No growth occurred at pH 2.4 or pH 12.2. In the broth growth occurred at all concentrations tried between pH 2.96 and pH 11.42. No growth occurred in broth with initial concentration of pH 2.65 or pH 11.58.

The wide range here shown is perhaps interesting in view of the specialized nature of the parasite.

Studies are in progress to learn the optimum concentration for growth, and the effect of the growth of the fungus on the hydrogen-ion concentration of the medium

Two bacterial diseases of gladiolus. LUCIA McCULLOCH.

An undescribed leaf blight, particularly destructive to young stock, has been found on several varieties of gladiolus. The spots are translucent, usually angular, water-soaked, dark green, becoming brown. From these lesions there is a copious bacterial exudate in which soil particles become imbedded.

The organism, which produces a yellow, viscid growth on culture media, has been isolated repeatedly, its characters studied and its pathogenicity proved. The group number is 211.2322523. The name proposed for this organism is *Bacterium gummasudans*. A complete description of this disease has been submitted for publication.

The other disease, caused by *Bacterium marginatum* L. McC., was reported briefly in Science, August 5, 1921, as a rot occurring at the base of gladiolus leaves. Further study demonstrated that this organism is also the cause of a characteristic disease of gladiolus corms. Husk lesions are brown to black, causing holes or cracks. On the body of the corm the spots are circular, depressed areas, yellow to brown, horny in

texture, easily removed, leaving clean saucer-shaped pits. In these lesions of husk and corn the bacteria remain viable and pathogenic from season to season, thus providing a source of infection wherever the diseased corns are planted.

Minnesota sunflower diseases in 1923. A. W. HENRY AND H. C. GILBERT.

Septoria helianthi Ell. & Kell. and *Puccinia helianthi-mollis* (Schw.) Jackson together and separately, caused serious defoliation of *Helianthus annuus* L. in different sections of Minnesota this year, particularly on land which had borne several successive crops of sunflowers. One hundred per cent of the plants in such fields were commonly infected with both fungi. The damage was less severe in several instances where sunflowers were grown in rotation. The *Septoria* leaf spot was frequently more destructive than the rust. Both diseases first appeared on the cotyledons but the *Septoria* leaf spot spread more rapidly during the early part of the summer while the rust did not become abundant until later in the summer. Nineteen varieties of cultivated sunflowers were severely infected with these diseases at St. Paul. A downy mildew also occurred on nine varieties of late sown sunflowers at St. Paul and was apparently responsible for severe stunting of from ten to ninety per cent of the plants in different rows.

Fungous diseases of the China aster. W. O. GLOYER.

The following parasitic fungi on the China aster were studied: *Ascochyta asteris* (= *Phyllosticta asteris* Bres.), *Botrytis cinerea*, *Coleosporium solidaginis*, *Fusarium* sp., *Phytophthora* sp., *Rhizoctonia solani* and *Septoria callistephi*. The leaf spots caused by *Ascochyta*, *Botrytis*, *Coleosporium* and *Septoria* were controlled by spraying with Bordeaux mixture. *Ascochyta*, *Botrytis*, *Fusarium* and *Septoria* are seed borne and seed treatment with mercuric chloride proved more practical than spraying the plants. *Botrytis*, *Fusarium*, *Rhizoctonia* and *Septoria* may cause damping off and stem rot. *Septoria* is viable on two-year-old seed. As *Septoria* and other fungi winter on the stalks, they should be burned. Asters are susceptible to the other diseases studied during the seedling and seed producing periods, but the plants are attacked by *Fusarium* and *Septoria* at any period of their growth.

Where mercuric chloride (1-2000) was applied to the seedlings, *Septoria* and damping off were controlled. When applied at the time of transplanting no injury was noted where the soil was moist. Where the soil was dry the plants were badly stunted by 1-1280 and less by a 1-2000 solution. Three applications showed no injury if the root systems were well established.

Control chambers for plant environmental studies. JAMES G. DICKSON.

From the experimental studies conducted at Wisconsin on the relation of environment to disease development has evolved a series of chambers in which both temperature and relative humidity have been under control in the same compartment. Credit is gladly given Dr. Chas F. Hottes for the original suggestions in connection with these chambers although the methods of regulation are somewhat different from those developed by him. A gentle current of air is circulated continuously through the chamber by means of a small motor driven blower. The tempering of this air current is accomplished by deflecting part or all of it through a series of heating, cooling, and humidifying compartments by means of two, two-way mixing dampers controlled by a pneumatic, graduated

thermostat and humidostat respectively. As the instruments used in the chambers are regular, stock equipment used in commercial heating and ventilating installations, the cost of construction is reduced to a minimum. The average variation in temperature and relative humidity has been within 3° C., and 5 per cent respectively, even when operating in full sunlight or under artificial illumination. The same temperature control equipment installed in four greenhouses has given good temperature regulation from November 1 to May 15.

(Cooperative investigations by the Wisconsin Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.)

Tests of dehydrated culture media. G. H. COONS.

The development of dehydrated culture media for plant pathological work seems desirable. Besides the various media prepared for bacteriological uses, "cornmeal" agar, prune juice agar, and lima bean agar have been prepared by the Digestive Ferments Co. of Detroit, Mich., following standard formulae. The first named, "cornmeal" agar, is a synthetic agar containing only pure glucose, pure dextrin and "Bacto" agar. The others are dehydrated infusions with agar added. In addition to these media, Coons' synthetic broth and Czapek's synthetic broth have been prepared in dehydrated form. The following table shows the results of tests made with various organisms using these in comparison with home-made media of similar formula.

	<i>Sclerotinia cinerea</i>			<i>Penicillium fuscomaculans</i>		<i>Colletotrichum lindemuthianum</i>	
Agar Medium	pH	Mycelium	Spores	Mycelium	Pycnidia	Mycelium	Acervuli
"Cornmeal," Difco.	5.7	+	+++	++	+++	+++	+
Cornmeal, Home made	5.9	+	+	+	0	+++	0
Prune, Difco.	4.6	+++	+	+++	+++	+++	+
Prune, Home made	4.4	+++	+++	+++	+	+++	+
Lima Bean, Difco.				++	++	+++	++++
Lima Bean, Home made				+++	++++	+++	+++++
Coons' Synthetic, Difco.	5.5	+++	++	++++	++	++++	++
Coons' Synthetic, Home made	5.15	+	+++++	+++	++++	+++	+++++
Czapek's Synthetic, Difco.	5.4	<i>Sterigmatocystis violacea</i> made heavy growth, with abundant spores.					
Czapek's Synthetic, Home made	5.2	<i>Sterigmatocystis violacea</i> made heavy growth, with abundant spores.					

Ephelis mexicana Fr., *Balansia hypoxylon* (Pk.) Atk. on sandbur, (*Cenchrus echinatus* L.). GEORGE F. WEBER.

During the summer of 1922 *Cenchrus echinatus* L. (Sandbur) was found in the vicinity of Gainesville, Florida, often severely attacked by *Ephelis mexicana* Fr. The fungus attacked the inflorescence of the host plant when it was still within the sheath. The inflorescence then was not able to emerge from the boot. The tillers were decidedly stunted but not killed. The green color of the sheath was somewhat darker than normal when the fungus was present. As the fungus developed the whole inflorescence was involved. A soft spongy white mass of mycelia completely covered the floral parts. This gradually darkened to a glossy, jet black and became hard, forming a sclerotium from 75 to 150 mm. long, 2 to 4 mm. wide, often somewhat flattened and tapered more toward the bottom than the top. These sclerotia were collected and placed in a moist chamber. After two weeks small *Peziza*-like cups containing conidia developed from the sides of the sclerotia. The conidia germinated readily and grew on potato agar poured plates. After about four weeks, more growths appeared on the sclerotia. A stroma developed which was rough, black, globose, 2 to 5 mm. in diameter. It was pushed up by a stipe often 3 cm. in length. The stroma was filled with perithecia which contained asci and ascospores very similar to *Balansia hypoxylon* (Pk.) Atk. Later, during the winter the two stages were found out of doors buried in sand where diseased plants of *Cenchrus echinatus* L. had previously grown.

Infection-court in radish black-root. JAMES B. KENDRICK.

The natural wound at the point where the secondary root emerges from the cortex of the primary root of the radish appears to be an avenue of infection for the black-root fungus (*Rheosporangium aphanidermatus* Edson). Examination under the binocular microscope of 258 incipient lesions on 45 young White Icicle radishes showed that 98 per cent were located in the cortex of the primary root immediately surrounding the base of a secondary root. The fungus is intercellular. Evidences of systemic infection have been found. In young radishes grown in sterilized, inoculated soil, the fungus caused a blackening of the cortex of the stem, petiole, and leaf midrib and a lateral curling of the leaves. In field tests, the variety White Chinese has tended to escape infection.

Sugar beet seed disinfection with formaldehyde vapor and steam. CAROLINE RUMBOLD.

Exposing sugar beet seed balls for 20 minutes to a mixture of formaldehyde vapor and steam with a temperature of 140° F. has been found sufficient in laboratory tests to kill fungus spores and bacteria ordinarily associated with the seed balls.

This treatment impregnates the outermost tissues of the seed balls with formaldehyde without starting the germination of the seed or injuring the viability of the seed. Even after four years' storage, traces of formaldehyde have been found on the seed balls, but a field test in Virginia showed no decrease in germination of the seed. Field tests in Colorado with treated seed are reported to have increased production of sugar per acre. In the author's opinion the increased production was due to destruction of fungus: pores or bacteria on the seed balls, although these points have not been experimentally determined.

PHYTOPATHOLOGY

VOLUME XIV

FEBRUARY, 1924

NUMBER 2

THE RUST OF COWPEAS

F. D. FROMME¹

WITH PLATE I

In a previous paper² the writer, together with S. A. Wingard, briefly discussed a rust of the cowpea (*Vigna sinensis* (L.) Endl.) which was found to be distinct in pathogenicity from the bean rust (*Uromyces appendiculatus* (Pers.) Fries) to which it has commonly been assigned. Additional study of the cowpea rust has shown that it is distinct in morphology from the bean rust, as well as in pathogenicity, and it is presented herein as a clearly defined species.

MORPHOLOGY

The most distinctive feature is found in the location of the urediniospore germ-pores; a character of marked taxonomic value which has been used extensively by Arthur and other workers in his laboratory.³ The urediniospores of *U. appendiculatus*, according to Arthur's description in the North American Flora, show 2, rarely 3, equatorial pores. My study of the species on kidney bean confirms this as to location of pores. They are invariably in the equatorial zone and are always 2 in number (Fig. 1, B; Pl. I, fig. 2). I have seen no spores, however, in which 3 pores could be clearly distinguished. The urediniospores of the cowpea rust also show 2 pores but their position is distinctly superequatorial (Fig. 1, A; Pl. I, fig. 1). They are more distinct than are those of bean rust and are often seen in the untreated spore; they are clearly visible after treatment with lactic acid. The pores of bean rust are not easily seen except after treatment and then, as a rule, only when the spore is

¹ Paper 60 from the Department of Plant Pathology, Virginia Agricultural Experiment Station.

² Fromme, F. D., and S. A. Wingard. Varietal susceptibility of beans to rust. Jour. Agr. Res. **21**: 385-404. 1921.

³ Arthur, J. C., and F. D. Fromme. Taxonomic value of pore characters in the grass and sedge rusts. Mycologia **7**: 28-33. 1915.

in such a position that the pores appear in the side walls. This difference in visibility is probably due to the darker wall of the spore from cowpea. A slight distinction is also seen in the surface markings of the spores; the echinulations are closer and less prominent in the cowpea rust than in the bean rust. The uredinia on the cowpea are darker in color and larger, as a rule, than those on bean (Pl. I, fig. 3).

The teliospores are very similar (Fig. 1, A and B), but those from cowpea usually show a slightly thinner side wall and less apical thickening; they are also of the lepto or non-resting type, a point that will be discussed later, while the teliospores of bean rust apparently require a considerable after-ripening period before they are capable of germination.

The aeciospores of the two rusts are indistinguishable (Fig. 1, A and B) but the arrangement of the aecial groups is distinctive. Fisher¹ describes the aecia of *U. appendiculatus* as often in "kreuz formige" groups and this is true of the aecia on *Phaseolus* seen by the writer. The groups suggest crosses (Pl. I, fig. 4) or rosettes (Pl. I, fig. 5) according to the number of aecia. The aecial groups are small, the average number of aecia to the group being 7 and the range from 4 to 12. This grouping has not been seen in the cowpea rust. The aecia here are in the usual annulate group on slightly raised areas (Pl. I, fig. 6). The groups are considerably larger than are those on bean and they average about 50 aecia to the group.

The presence of superequatorial pores in the rust of *Vigna* has been noted by Arthur,² but at that time he apparently considered this a varietal distinction rather than a specific one. In a discussion of material on *Vigna repens* and *V. vexillata* from Porto Rico he writes:

While the pores in the urediniospores of this species are usually two or three, and equatorial, they are sometimes four in number and sometimes are distinctly superequatorial. The Stevens' collections from Porto Rico show only uredinia, and the spores are 2-pored. On *Phaseolus* the pores are mostly equatorial, but on *Vigna* they are markedly superequatorial.

He makes a similar comment in a later paper³ as follows:

The collection on *Vigna vexillata*, made by Mr. Johnston, shows urediniospores with two or three pores, varying from equatorial to markedly superequatorial, a condition also noted in the Porto Rican rusts on this host genus. The species is autoecious, but

¹ Uredineen der Schweiz, p. 19.

² Arthur, J. C. Uredinales of Porto Rico. *Mycologia* 7: 185 1916.

³ Arthur, J. C. Uredinales of Cuba. *Memoirs Torrey Bot. Club* 17: 129. 1918.

the pycnia and aecia have not been reported from the tropics, and even telia are somewhat rare. The rust is cosmopolitan on *Dolichos*, *Phaseolus*, *Strophostyles*, *Vigna*, and probably other genera.

SYNONYMY OF COWPEA RUST

The foregoing treatment of the cowpea rust is that commonly followed; it is referred to *U. appendiculatus* in all taxonomic treatments of this species seen by the writer and commonly passes under this name in current literature. There are, however, eleven rust species which have been described on species of *Vigna*. Four of these are species of *Accidium*, two species of *Uredo*, and five species of *Uromyces*. They are listed in the following:

Accidium vignae Cooke, on *Vigna marginata*, Natal, South Africa, Grev. 8: 71. 1879; *A. nigro-cinctum* Pat. & Har., on *Vigna* sp., French Indo-China, Bull. Myc. Fr. 22: 116. 1906; *A. caulicola* P. Henn., on *Vigna* sp., Dembo, central Africa, An. Mus. Congo 2: 95. 1907; *A. decipiens* Syd., Monog. Ured. 4: 223. 1923.

Uredo purpurascens P. Henn., on *Vigna* sp., central Africa, An. Mus. Congo 2: 93. 1907; *U. vignae* Bres., on *V. lutea*, St. Thomas, West Indies, Rev. Myc. 13: 66, for 1891.

Uromyces vignae Baryl., on *Vigna vexillata*, Simla, India, Jour. Asiat. Soc. Bengal 60: 211. 1891; *U. pazschkeanus* P. Henn., on *Vigna* sp., Abyssinia, Bull. Herb. Boiss. 1: 107. 1893; *U. vignicola* P. Henn., on *Vigna* sp., Africa, Eng. Bot. Jahrbr. 38: 103. 1905; *U. punctiformis* Syd., on *V. strobilophora*, Mexico, Ured. 1513, 1901; *U. vignae luteolae* P. Henn., on *V. luteola*, Africa, An. Mus. Congo 2: 95. 1907.

Only two of these species, *U. vignae* Baryl., and *U. vignae luteolae* P. Henn., can be assigned with any degree of certainty to the rust of cowpea under discussion. Although the writer has seen no material of Baryl's species there can be little question as to its identity. The type collection was made near Simla, India, on *Vigna vexillata* (L.) A. Rich.,¹ a cosmopolitan species which is represented in the Arthur herbarium² by three rust collections, two from Cuba and one from Porto Rico. These have been examined and found identical with the rust of *V. sinensis*. Baryl describes the urediniospores of *U. vignae* as:

¹ It is to be noted that Baryl cites the host as *V. vexillata* Benth. but Richard's name antedates this. The two refer to the same species.

² The writer is indebted to Fr. J. C. Arthur and to Purdue University for the loan of herbarium material, and also to Dr. Arthur for critical reading of this manuscript.

Brownish red, oval to round, thin walled, very spiny and with a few immature teleutospores among them. They measured when fresh and just wetted $28-29 \times 19-18 \mu$. The teleutospores are deep brown, oval, very deciduous, with a portion of colourless stalk adherent, with a pale-brown, shallow mammilla, and a smooth surface. The fresh spores just wetted measured $35-27 \times 22-20 \mu$. The portion of adherent stalk measured up to 40μ in length.

The close similarity of these measurements with those of the species under discussion leaves little doubt as to their identity. It seems probable also that *U. vignae luteolae* is identical with this species as it is listed by Sydow as synonymous with *U. appendiculatus* to which he also assigns the rust of *V. sinensis*.

None of the species of *Aecidium* described from *Vigna* can be placed with any certainty and probably none of them relates to the rust in question. *Aecidium caulicola* has small aeciospores, $10-15 \mu$ according to Hennings, and *A. vignae* has aecia in large groups on strongly hypertrophied areas of the leaf blade and petiole.

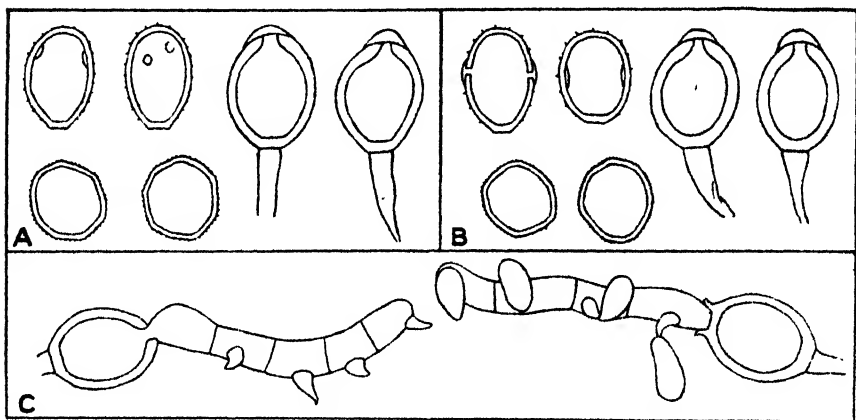


FIG. 1. A. Aeciospores, urediniospores and teliospores of *Uromyces vignae* from *V. sinensis*. The urediniospores show 2 superequatorial pores. B. Aeciospores, urediniospores and teliospores of *U. appendiculatus* from *Phaseolus vulgaris*. The urediniospores show 2 equatorial pores. C. Germinating teliospores of *U. vignae*.

Uredo vignae has been transferred by Arthur (Bull. Torrey Club 44: 509. 1917) to *Phakopsora*, a genus in which the uredinia are bordered by a delicate cellular peridium, and *U. purpurascens* has small urediniospores.

The urediniospores of *Uromyces punctiformis* are thin walled with 2 inconspicuous, approximately equatorial pores, and are readily distinguished from those of *U. vignae*. The telia of this species are minute and the teliospores are punctate and have long pedicels. Arthur has placed it under *U. appendiculatus* (N. Am. Flora 7³: 257. 1912) but it appears to the writer to be a valid species. It is known only by the type collection. *U. vignicola* although described as a rust is said to be a *Synchytrium*. The status of *U. pazzschkeanus* is in doubt. According to Sydow the teliospores are distinguishable by thick pedicels which swell in water. No urediniospores are described. A specimen which comes from the region of the type, collected by G. Schweinfurth on *Vigna* sp., Eritrea, Akkur, February 14, 1894, and labeled *U. pazzschkeanus*, shows urediniospores $20-22 \times 23-27 \mu$, with 2 superequatorial pores, and is identical with *U. vignae* in other respects. The specimen may be incorrectly named, however, and it seems best to leave the assignment of this species open for the present.

A critical examination of material previously listed under *U. appendiculatus* shows the following to be additional hosts for *U. vignae*:—*Dolichos lablab*, *Phaseolus truxillensis*, *Vigna repens* and *V. sesquipedalis*. A point of unusual interest is found in the occurrence of both species on *Dolichos lablab*. *U. vignae* occurs on two collections of this host from Cuba, as cited later under hosts, and on one from India, while a collection from Jamaica, lower slopes of Mt. Moses, April 14, 1903, L. M. Underwood, and one from Krakau, Bot. Garden, August, 1891, M. Raciborski, both bear rusts readily identified as *U. appendiculatus*. All material seen on the other hosts of *U. vignae* as listed is referable to this species. The occurrence of *U. vignae* on *Phaseolus truxillensis* is somewhat surprising in view of the fact that no other species of *Phaseolus*, so far as is known, bears this rust. *Dolichos melanophthalmus* DC. which is found to bear *U. vignae* is said by Piper¹ to be a cultivated, blackeyed cowpea of the Mediterranean region synonymous with *V. sinensis*.

The following hosts appear to be correctly placed under *U. appendiculatus*: *Phaseolus adenanthus* G. Meyer, *P. anisotrichus* Schl., *P. atropurpureus* Moc. & Sesse, *P. coccineus* Jacq., *P. disophyllus* Benth., *P. lunatus* L., *P. obrallatus* Schlecht., *P. polystachyus* (L.) B. S. P., *P. retusus* Benth., *P. vulgaris* L. The status of the rust on *P. lathyroides* L., *P. sinuatus* Nutt., *Strophostyles helvola* (L.) Britton, *S. pauciflora* (Benth.) S. Wats., and *S. umbellata* (Muhl.) Britton is not so clear.

¹ Piper, C. V. Agricultural varieties of cowpea. U. S. Dept. Agric., Bur. Pl. Ind. Bull. 229. 1912.

These have all been referred to *U. appendiculatus* but all show pores slightly above the equator, somewhat intermediate in position between the equatorial pores of this species and the distinctly superequatorial pores of *U. vignae*. They cannot be placed properly with the latter species and they are atypical for *U. appendiculatus*. It is possible that a third species is involved. I have attempted to culture the *Strophostyles* rust on both beans and cowpeas without success but the circumstances attending the attempts do not warrant a statement that the rust will not pass to either under optimum conditions. Arthur¹ has shown that the *Strophostyles* rust is autoecious and that it has teliospores of the resting type by producing aecia in the spring with overwintered teliospores.

It seems desirable to supply a more detailed description of the rust of *Vigna* than that given by Barclay. The pycnia and aecia have not been described and the uredinia and telia have features of taxonomic value not included in Barclay's description. The species is also transferred to the genus *Nigredo* according to Arthur's treatment of the rusts.

Nigredo vignae (Barcl.) comb. nov.

Uromyces vignae Barcl. Jour. Asiat. Soc. Bengal **60**: 211. 1891.

Uromyces vignae luteolae P. Henn. An. Mus. Congo **2**: 95. 1907.

0. Pycnia epiphyllous, in small circular groups, honey-yellow, becoming brownish, globose or broadly so, 100-125 μ in diameter; ostiolar filaments short.

I. Aecia chiefly hypophyllous and petiolicolous, in circular groups, 2-4 mm. across, often with annular arrangement, low-cupulate, small, 0.2-0.3 mm. in diameter; peridium whitish, rather evanescent, margin spreading, irregularly lacerate; peridial cells rhomboidal or oblong, slightly imbricated, 16-20 \times 20-25 μ , the outer wall 3-5 μ transversely striate, smooth, the inner wall 2-3 μ , verrucose; aeciospores ellipsoid or oblong ellipsoid, 16-20 \times 20-26 μ ; wall colorless, 1-1.5 μ , minutely and closely verrucose.

II. Uredinia amphigenous and petiolicolous, scattered, roundish, rather large, about 1 mm. or less in diameter, soon naked, chestnut-brown, ruptured epidermis evident; urediniospores ellipsoid or ovate-ellipsoid, 18-22 \times 24-30 μ ; wall cinnamon-brown, moderately thin, 1.5-2 μ , finely and closely echinulate, the pores 2, readily distinguished, markedly superequatorial.

¹ Arthur, J. C. Cultures of Uredineae in 1903. Jour. Myc. **10**: 14. 1904.

III. Telia amphigenous and petiolicolous, roundish, about 0.5 mm. in diameter, early naked, blackish-brown, somewhat pulverulent, ruptured epidermis evident; teliospores broadly ellipsoid, $20-25 \times 27-35\mu$, rounded or obtuse above, usually rounded below; wall dark chestnut-brown, smooth, moderately thick, $2-2.5\mu$, apex $4-6\mu$ including the hyaline, hemispherical umbo; pedicel hyaline, fragile, rarely equalling the spore length; germinating at maturity.

The collections listed below have been examined by the writer.

On *Dolichos lablab* L., Santiago de las Vegas, Cuba, November 3, 1917, J. R. Johnston; Regla, Prov. Havana, Cuba, April 8, 1903, J. A. Shafer (from phanerogamic specimen); Kanaighat, India, May 24, 1905, E. J. Butler (Sydow Ured. 2101).

On *Phaseolus truxillensis* H.B.K., San Jose, Costa Rica, January 10, 1916, Holway, 397.

On *Vigna repens* (L.) Kuntze, Miami, Florida, March 25, 1903, Holway; Punta Rassa, Lee County, Florida, February 26, 1916, P. C. Standley, 12670; Arecibo, Porto Rico, May 21, 1913, F. L. Stevens, 1760; Mayaguez, Porto Rico, March 3, 1916, Whetzel & Olive, 201; Bahia Honda, Pinar del Rio, Cuba, December 14, 1910, Percy Wilson (from phanerogamic specimen).

On *Vigna sesquipedalis* (L.) W. F. Wight, Honomo, Hawaii, May 1920, L. O. Kunkel.

On *Vigna sinensis* (L.) Endl., Alhambra, California, Fall, 1919, D. C. Milbrath; Ames, Iowa, Fall, 1901, Estella Rhinehart; Lafayette, Indiana, October 17, 1902, J. C. Arthur (N. Am. Ured. 381); Lafayette, Indiana, October 26, 1903, J. C. Arthur; Suling, Texas, August 26, 1909, Heald & Wolf, 2260; Leesville, Texas, August 1, 1902, C. L. Shear; Brownsville, Texas, May 10, 1912, W. P. Carr; Manchester, Missouri, September 26, 1906, H. Von Schrenk; Columbia, Missouri, September 23, 1906, B. M. Duggar; Grady, Alabama, July, 1923, S. A. Wingard; Pensacola, Florida, July 26, 1909, G. W. Carver (N. Am. Ured. 86); Bell, Maryland, August 2, 1921, J. T. Rogers; Arlington Farm, Virginia, September 16, 1907, G. Graham; Blacksburg, Virginia, August 7, 1922, S. A. Wingard; Oahu Sugar Company, Oahu, Hawaii, July 23, 1919, Lyon; Nujingyan, Burma, January 24, 1908, E. J. Butler (Sydow Ured. 2451); Parma, Italy, July, 1874, Passerini (Thüm. Myc. Univ. 40).

On *Vigna vexillata* (L.) A. Rich., Toa, Baracoa, Cuba, April 17, 1916, J. R. Johnston, 586; Campo Florido, Prov. Havana, Cuba, July 18, 1912, Bro. Leon (from phanerogamic specimen); Mayaguez, Porto Rico, June 14, 1913, F. L. Stevens, 2216.

On *Vigna sp.*, Eritrea, Akur, February 14, 1894, G. Schweinfurth.

The locality of the type collection is near Simla (on Tara Devi), India, on *Vigna vexillata* (L.) A. Rich. (*V. vexillata* Benth).

GEOGRAPHIC DISTRIBUTION

A survey of recent literature gives a number of additional localities and adds materially to the distribution of the rust of cowpea as shown by the herbarium material examined. The rust is, of course, cited as *U. appendiculatus*. An examination of specimens would be necessary before these citations could be placed without question under *U. vignae* but there seems little doubt that the following are referable to this species.

On *Vigna luteola*, Columbia, Central Andes, Mem. Soc. Neuchat. 5: 462. 1914; Argentine, Hedwigia 35: 223. 1898.

On *Vigna sesquipedalis*, Philippine Islands, Leaf. Phil. Bot. 6: 2076. 1914.

On *Vigna sinensis*, Japan, An. Myc. 20: 82. 1922; Philippine Islands, Phytopathology 9: 139. 1919; Ceylon, Yearbook Ceylon Soc. Agr. 1919-1920: 117. 1919; Cuba, Informe Estac. Exp. Agron. Cuba 1918 1919, 1919-1920: 723-763. 1921; China, An. Phytopath. Soc. Japan 1: 66. 1921; Russia, Bur. Myc. & Phytopath. Petrograd 1: 23-41. 1915; India, An. Myc. 10: 256. 1912.

Apparently the rust of *Vigna* is cosmopolitan and occurs practically coextensively with the distribution of its hosts in southern Europe, Asia, Japan, the Philippines, the Hawaiian Islands, Africa, South America, Central America, the West Indies, and the United States especially in the southern part. It is recorded from the states of Maryland, Virginia, Alabama, Florida, Indiana, Iowa, Missouri, Texas, and California.

INFECTION STUDIES

The rust material used in the infection studies has been obtained from several sources. The first material came from D. C. Milbrath and was collected at Alhambra, California, in the fall of 1919. It consisted of fresh leaves of Blackeye cowpea bearing viable urediniospores of *U. vignae*. The rust was established in the greenhouse on Blackeye plants and was carried over winter with occasional transfers.

A sowing of 18 varieties of cowpea and 19 varieties of kidney bean was made in the field at Blacksburg, Virginia, in the spring of 1920 and after

suitable growth these were inoculated with urediniospores taken from Blackeye plants in the greenhouse. The inoculation was made on July 10 and uredinia were first noted on the plants of Blackeye on July 22. The infection had developed vigorously on this variety by July 29 and on this date a careful inspection of the other varieties of cowpeas and beans was made. No infection was found on any of the beans and infection of the cowpeas was restricted to four varieties of the Blackeye type recorded as follows:

Vigorous infection: Blackeye.

Slight infection: Large Blackeye, Extra Early Blackeye, Ramshorn Blackeye.

Flecks only: Black, Brabham, Clay, Cream Crowder, Gallavant, Groit, Iron, New Era, Red Ripper, Taylor, Two-Crop Clay.

No flecks nor sori: Crowder, Rice or Cream Pea, Whippoorwill.

The infection at this time consisted of uredinia and telia, the latter occurring especially on the older leaves. It continued to develop vigorously on the Blackeye plants which suffered severe defoliation in consequence. In late August, much to our surprise, an abundant development of aecia was noted on the plants of this variety. Uredinia and telia were found in considerable numbers on Extra Early and Ramshorn Blackeye at this time but there were no aecia and none also on Large Blackeye which showed only slight infection. There were no sporulating sori on any of the other varieties.

An attempt to carry the rust over winter in the greenhouse was a failure owing to the low temperatures maintained which were unsuited to the growth of cowpeas. During the spring of 1921 Blackeye cowpeas with other varieties were sown in the same location in the field as in 1920 in the hopes that infection might result from over-wintered material, but no infection occurred throughout the season. A culture of the rust from Blackeye was again obtained, however, on August 28, 1921, from the farm of the County Experiment Station at Chatham, Virginia. The rusted Blackeye plants were in a variety test which also included the varieties Black, Brabham, Clay, Groit, Iron, Taylor, New Era and Whippoorwill, none of which showed infection. Although the rust was in the telial stage only an attempt to establish a culture was made on Blackeye plants in the greenhouse on September 10. Pycnia followed by aecia appeared on the inoculated plants on September 19. A second sowing of the material from Chatham was made on other Blackeye plants on September 19 and pycnia were obtained on September 28.

Aeciospores from the culture of September 19 were used as inoculum

in the greenhouse on October 18 on plants of Blackeye and Black cowpea, on adzuki bean (*Phaseolus angularis* (Willd.) W. F. Wight), asparagus bean (*Vigna sesquipedalis*), hyacinth bean (*Dolichos lablab*), mung bean (*P. aureus* Roxb.), bubb catjang (*V. catjang* (Burm.) Walp.), rice bean (*P. calcaratus* Roxb.), sword bean (*Canavalia gladiata*), scarlet runner (*P. multiflorus* Willd.), and urd bean (*P. mungo* L.). Infection (uredinia) was obtained only on Blackeye. A repetition of the foregoing test was made November 1, using urediniospores from Blackeye on the same series of plants. Vigorous infection was obtained on Blackeye and none resulted on any of the other plants. A third attempt made on the same series of plants growing in a garden at Blacksburg in the summer of 1922 gave the same results. No plants except those of Blackeye showed infection. Several additional attempts were made to secure infection with the cowpea rust on a number of varieties of kidney bean and lima bean, but all were without success.

From the foregoing it is apparent that the rust of cowpea is closely limited in its host range. Of the varieties of cultivated cowpeas tested it has infected only Blackeye and closely related strains and has produced no infection on the kidney, lima or other types of bean included in the tests.

Piper's observations (l. c.) on the development of rust in cowpeas under comparative tests at Arlington, Virginia, furnish additional data as to varietal susceptibility. He writes:

Rust is a disease to which most standard American varieties of cowpeas are immune. Many recently imported varieties, especially from China and India, are, however, very susceptible to this disease and suffer severe injury from it. That other varieties are completely immune to rust would appear from the fact that they are never affected even when growing contiguous to a rusted variety on the same ground for several years in succession, which has been the experience at Arlington Farm. This disease was very much in evidence at Arlington in 1908 and 1909, but was entirely absent in 1910.

Piper's tests included a large number of named varieties and in addition a number of importations from foreign countries many of which are listed by number only. Notes as to behavior with respect to rust infection are included in the descriptions and discussions of the varieties and introductions. The named varieties of cowpea on which the presence of rust is recorded are: Browneye, Chinese Black, Chinese Red and Chinese Whippoorwill. It also occurred on a number of the unnamed introductions of cowpea, catjang and asparagus bean. The following varieties of cowpea are recorded as free from rust: Ayrshire, Black, Black

Crowder, Blackeyed Lady, Brabham, Brown Coffee, Brown Crowder, Browneye Crowder, Cotton Patch, Cream, Delaware Red, Early Black or Congo, Early Blackeye, Early Red, Grayeye, Groit, Guernsey, Holstein, Iron, Lady, Louisiana Wild, Michigan Favorite, New Era, Old Man, Panmure Early Wonder, Peerless, Powell Early Prolific, Purple-Podded Clay, Ramshorn Blackeye, Red Crowder, Red Ripper, Red Whippoorwill, Red Yellowhull, Self-Seeding Clay, Sixty-Day, Small Black Crowder, Smallpox, Southdown, Speckled Crowder, Taylor, Unknown, Unknown Blackeye, Warren New Hybrid, Watson, Whippoorwill, Whippoorwill Crowder, White Giant, Wight Black Crowder.

It is to be noted that none of the varieties recorded as susceptible to rust by Piper were included in our tests and that the observations with respect to those varieties which were included in both tests are in agreement except that the writer obtained moderate infection on Early Blackeye and Ramshorn Blackeye while Piper records these varieties as free from rust. Certain introductions of asparagus bean were found to be susceptible by Piper while others were rust free. My attempts to infect asparagus bean were made with a single variety, Yard Long, and it seems probable that successful infection might have been obtained if more varieties or strains had been available. It is possible, of course, that there are two or more biologic strains of the cowpea rust. According to L. O. Kunkel the rust of asparagus beans is common in the Hawaiian Islands. In a letter dated March 14, 1920, he writes:

I have not found rust on beans out here (Honolulu) and there is no record of its occurrence here at the station. However, what is supposed to be the same thing is common enough on the Yard Long bean, *Vigna* sp. I have collected rust on this host on this island and also on the island of Hawaii. Phaseolus plants are always free from rust.

Although I have made no extended test of teliospore germination with either the cowpea or bean rust it is evident from their behavior in culture that *U. vignae* has teliospores of the non-resting type, while those of *U. appendiculatus* require a considerable period of after-ripening prior to germination. Aecia of *U. vignae* have been produced in the field in August from teliospores produced during the same season, and also in the greenhouse on several occasions during fall, winter and spring from teliospore inoculation. This occurred in two separate trials in September, 1921, with teliospores taken from the field and again in November, 1922. Teliospores taken from the field November 24, 1922, showed germination on this date but none were viable in later tests. A culture carried through the winter of 1919 in the greenhouse produced aecia in the spring from teliospore inoculation. The rust had gone through

several uredinial generations in the greenhouse and the teliospores used as inoculum had been produced but a short time previously.

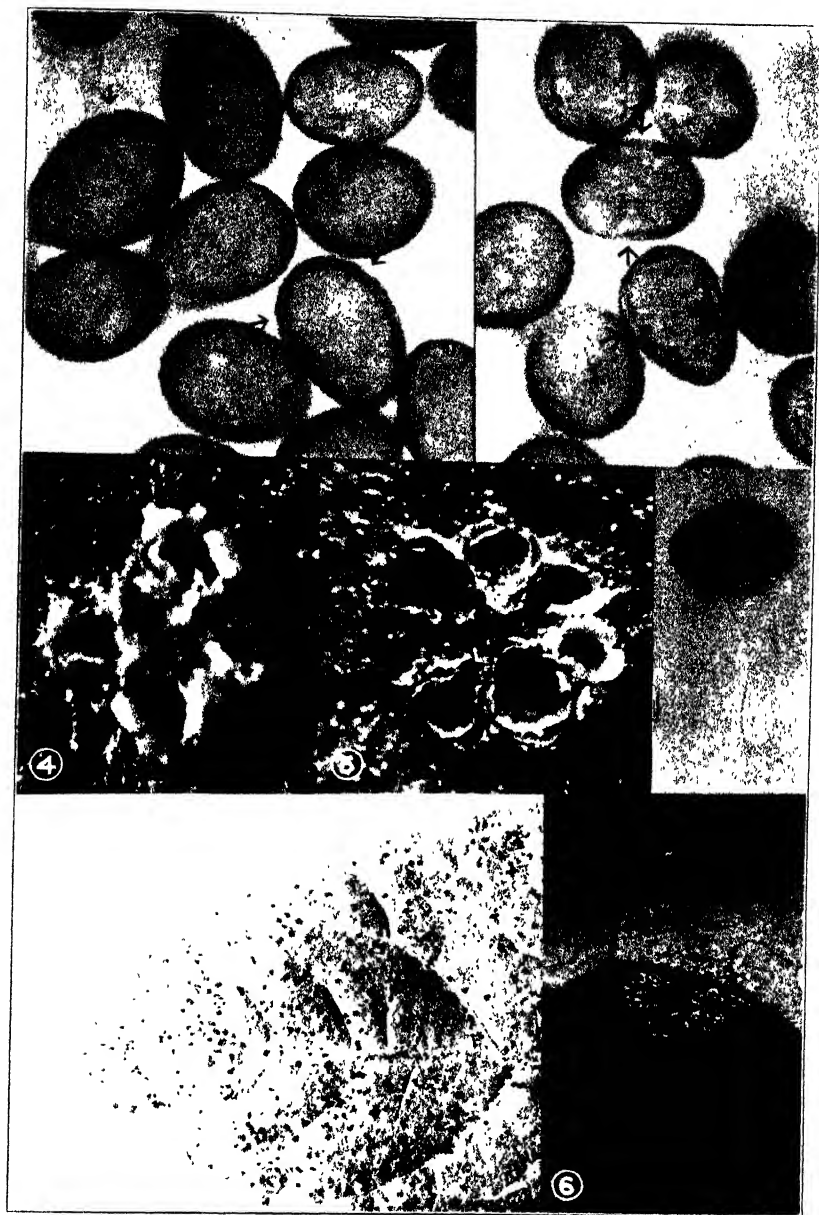
In contrast with this behavior of the cowpea rust the bean rust during seven years of experimental study in both greenhouse and field has never produced aecia. The writer has watched for the initial appearance of bean rust in gardens in spring and early summer and invariably uredinia only have been observed, followed later in the season by telia. Teliospores at the time of maturity have been used as inoculum without results. No systematic attempt at the overwintering of teliospores has been made and evidence in regard to their germination is lacking. Such evidence as may be gained from a study of herbarium material indicates that aecia of bean rust are rare in the United States and it seems probable that the teliospores do not function as a rule in the overwintering of the fungus. Specimens of bean rust in the Arthur herbarium and in that of the U. S. Department of Agriculture have been examined, and although a great many collections from North America are present only one shows aecia; this is on *P. vulgaris* from LaCrosse, Wisconsin, July 25, 1908. A collection by Underwood on *Phaseolus* sp. from Jamaica, September 2-10, 1906, also shows aecia but the identity of the host is somewhat doubtful. Several European collections which show aecia have been seen by the writer but they are said by Fisher (l. c.) to occur but rarely in Europe. I know of but one additional collection from North America on *Phaseolus* which shows aecia. This material which is of a pole bean (*P. vulgaris*) was sent me from a garden at Blacksburg, Virginia, on July 8, 1916. I did not know at the time that aecial production in the bean rust was unusual and did not visit the garden to study the case.

So far as I am aware no one has carried the bean rust through its complete cycle or developed aecia from teliospore infection except possibly deBary¹ who, however, gives no details of his work with this species. He states that he obtained the same results with the rust of beans as with *Uromyces fabae* for which he describes cultures establishing the relation between the three spore forms. There seems no question as to the autoecism of the bean rust but the fact has not been established on as definite a basis as is desirable.

SUMMARY

The rust of cowpeas which has commonly been considered identical with the rust of beans, *Uromyces appendiculatus*, is presented as a clearly

¹ deBary, A. Recherches sur le developement de quelques champignons parasites. An. Sci. Nat. Bot. IV. 20. 1863.



RUST OF COWPEA

defined species and is assigned to *Uromyces vignae* as described by Barclay from *Vigna vexillata*. A new description of the species is given. Marked distinguishing features between the two species are found in the grouping of the aecia, the location of urediniospore germ pores, and in the germination of the teliospores. The teliospore of *U. vignae* is of the non-resting type while that of *U. appendiculatus* is of the resting type.

Occurrence of *U. vignae*, from a study of herbarium material, is recorded on four species of *Vigna*, one of *Dolichos* and one of *Phaseolus*.

Infection studies with a strain of the rust obtained from the Blackeye variety of cowpea show it to be closely restricted in its host range. It has infected only a few varieties or strains of the Blackeye type. The great majority of cowpea varieties grown in the United States are immune or highly resistant. No infection has been obtained on hyacinth bean or asparagus bean which are hosts according to the taxonomic treatment. This failure may be due to lack of the proper variety or strain of these hosts for testing or it may be that there is more than one biologic strain of the rust.

Uromyces vignae has produced aecia under field conditions in August and during fall, winter and spring in the greenhouse from newly matured teliospores. It is the only full-cycled, autoecious rust known to the writer which completes its full cycle under greenhouse conditions.

EXPLANATION OF PLATE I

FIG. 1. Urediniospores of *Uromyces vignae* from Blackeye cowpea. The pores are designated by arrows and are superequatorial. Approximately 900 \times .

FIG. 2. Urediniospores of *U. appendiculatus* from Tennessee Green Pod bean. The pores, designated by arrows, are equatorial. Approximately 900 \times .

FIG. 3. Uredinia of *U. vignae* on a leaf of Blackeye cowpea. About 1½ \times .

FIG. 4. Aecia of *U. appendiculatus* from *Phaseolus vulgaris* showing "kreuz formige" grouping. The group contains 4 aecia. About 30 \times .

FIG. 5. Aecia of *U. appendiculatus* from *P. vulgaris* showing rosette grouping. The group contains 7 aecia. About 30 \times .

FIG. 6. Aecia of *U. vignae* on a leaf of Blackeye cowpea showing annulate grouping. About 5 \times .

FIG. 7. Urediniospore of *U. appendiculatus* showing the germ-tube issuing from an equatorial pore. Approximately 600 \times .

CURLY LEAF TRANSMISSION EXPERIMENTS

HENRY H. P. SEVERIN

WITH ONE FIGURE IN THE TEXT

DIRECT INOCULATION WITH JUICE FROM CURLY LEAF BEETS IN WHICH
THE DISEASE HAD BEEN PRODUCED BY THE BEET LEAFHOPPER
(*EUTETTIX TENELLA* BAKER)

Smith and Bonequet (4) failed to produce curly leaf by artificial inoculation with the juice of diseased beets, the liquid being atomized "upon uninjured surfaces, through large and small wounds in the leaves, petioles and roots, and by inserting the material into various parts of the plant in capillary glass tubes which were broken off and allowed to remain in the tissue." These inoculations were made at various degrees of temperature and humidity, but all without effect.

During the past five years mostly failures have been recorded in our endeavor to cause curly leaf by inoculating the petioles of healthy beets at some distance from the crown with juice from blighted beets in which the disease had been produced by the beet leafhopper (*Eutettix tenella* Baker). The exudation from the leaves of curly leaf beets in the field, such as the clear viscid liquid which later becomes black and sticky and upon drying forms a brown crust, when inoculated in all stages into the petioles of healthy beets failed to produce curly leaf.

In 1921 occurred the first typical case of curly leaf caused by inoculation. Juice was pressed from the two inner leaves of a beet showing an early stage of the disease,—namely, the transparent network of minute veins. The cleared veinlets were evident on September 9, and the juice was pressed from the beet on September 14, or five days later. A cooled flamed needle was forced about an inch into the crown of a healthy beet between the bases of the petioles and droplets of juice were placed in this wound by means of a sterilized pipette. The inoculated beet showed the first visible symptom of curly leaf on October 20, or 36 days after inoculation. Six other beets inoculated with the juice from three diseased beets failed to develop the disease.

Mr. C. C. Epling in his thesis work carried on under the direction of the writer, conducted daily inoculations with the juice from sugar beets upon which infective beet leafhoppers had fed from 1 to 8 days or until the first visible symptom of curly leaf appeared. A single case of curly leaf was produced in one of the inoculated beets in which the juice was pressed from the youngest or innermost leaf of an infected beet into an

incision in the petiole of a healthy beet. Thirty infective beet leafhoppers had fed on the infected beet for a period of five days and the cleared veinlets of curly leaf appeared at the end of eleven days. The first visible symptom of the disease in the inoculated beet developed at the end of seven days.

During 1923, nine typical cases of curly leaf were produced in beets about an inch in diameter by inoculating with juice from beet seedlings in an advanced stage of the disease,—namely, that characterized by nipple-like papillae and knot-like swellings on the distorted veins. The juice was first extracted from the leaves showing curly leaf symptoms and later from the beet root by means of a porcelain press. The juice was sucked up into dropping pipettes, these having a bulb in the center which prevented the liquid from entering the rubber bulb. A flamed needle after cooling was forced from 1 to 1½ inches into the crown of the healthy beet between the bases of the petioles. Several punctures were made in each beet but too many wounds will cause the outer leaves to die. A drop of beet juice was put over each hole and the needle was forced up and down in the wound. When the drop of beet juice disappeared another drop was put over the hole in the crown. During May, June and July, 62 healthy beets were inoculated with juice pressed from the leaves of curly leaf beets and 28 healthy beets were inoculated with the juice extracted from the roots of diseased beet seedlings. During the three months, healthy beets used as checks or controls were punctured in the crown with a cooled flamed needle. Three other lots of healthy beets were inoculated with juice pressed from healthy beet seedlings. All checks or control beets remained healthy.

The period from the date of inoculation until the earliest visible symptom of curly leaf appeared was as follows: 12, 12, 24, 25, 29 and 39 days respectively in six beets inoculated with the juice pressed from diseased beet leaves; 18, 20 and 24 days respectively in three beets inoculated with the juice extracted from the roots of curly leaf beets.

Non-infective beet leafhoppers, allowed to feed on the inoculated beets after curly leaf developed, transmitted the disease to healthy beet seedlings. Thirty-one lots of 20 non-infective beet leafhoppers enclosed in cages were allowed to feed on the nine inoculated diseased beets for a period varying from 2 to 7 days. Then each batch of 20 insects was transferred to a healthy beet seedling. The 31 beet seedlings developed the first visible symptom of curly leaf in from 2 to 13 days. On the other hand, non-infective beet leafhoppers, when allowed to feed on inoculated beets which did not develop curly leaf symptoms, failed to transmit the disease to healthy beet seedlings.

CAUSATIVE AGENT OF CURLY LEAF DISTRIBUTED IN ENTIRE BEET

Foliage.—The infective principle of curly leaf is generally distributed in the foliage and beet root. The evidence for this was obtained by feeding non-infective beet leafhoppers on various parts of the diseased beet and then transferring them to healthy beets. After a beet developed faint indications of transparent venation on a portion of the youngest leaf, non-infective adults were fed on the three outer leaves showing no visible sign of the disease. On each of the three days following 25 adults were transferred from the outer leaves of the infected beet to a healthy beet. The three beets used developed curly leaf. This experiment was repeated three times. In one case the first two beets remained healthy but the third showed the symptoms of the disease.

Hairy rootlets.—The causative agent of curly leaf was transmitted to healthy beets by non-infective beet leafhoppers which had fed on the hairy rootlets of diseased sugar beets. Badly blighted sugar beets obtained from the San Joaquin Valley were planted and after a new growth of hairy rootlets developed, these rootlets were removed and dropped on moist filter paper in a glass jar or caused to adhere to the sides of the jar. Thirty non-infective adults were confined in the jar, a fresh supply of the rootlets being added each day. Ten adults were removed daily and transferred to a healthy beet. The three healthy beets on which these insects had fed developed the disease.

Roots.—In similar experiments it was found that the disease-producing factor of curly leaf was transmitted to healthy beets by non-infective beet leafhoppers which had fed on the main roots and tap root of a diseased beet with the hairy rootlets removed.

Beet root.—The disease was also communicated to healthy beets when the non-infective hoppers had fed on the beet root with the main roots and hairy rootlets removed.

CURLY LEAF NOT TRANSMITTED FROM BEET TO BEET

The question has been asked frequently whether the soil is contaminated with curly leaf by the plowing under of badly blighted sugar beets. Fields of diseased beets are often plowed under during the spring and summer and beets planted on the same soil during the winter or following spring.

An experiment was conducted in the San Joaquin Valley to determine whether healthy beets could become infected with curly leaf as a result of the root system coming in contact with blighted sugar beets. A layer of badly diseased sugar beets were buried in the soil at the same depth at

which the land was plowed. The beets were inverted so that the tops rested 12 inches below the surface of the soil and the beet roots projected upward, thus preventing growth. The surface of the soil covering the buried beets was enclosed with a cage. Beet seeds were planted on March 8. On October 9, all beets were in a healthy condition in the cage.

Healthy beets failed to develop curly leaf at the end of six months when transplanted in flower pots so that the root system came in contact with the following parts of blighted beets: chopped leaves showing transparent venation only and others with the protuberances on the lower surface of the leaves; clusters of blighted bud leaves; chopped and sliced beet roots; and a combination of chopped leaves and beet roots. Two series of experiments were performed by planting European and American grown seeds, the latter obtained from blighted stechlings and mother beets. Not a single case of curly leaf developed.

In the last experiment the long tap roots of 16 healthy beet seedlings were twisted around the tap roots of 16 blighted beets. The former remained healthy during the period of three months that the experiment was continued. This experiment was first performed by Professor R. E. Smith with similar results.

RATE OF MOVEMENT OF CAUSATIVE AGENT OF CURLY LEAF IN PETIOLE

An experiment was conducted to determine the shortest time required for the infective principle of curly leaf to travel the length of a beet leaf petiole to the beet root. A potted sugar beet was placed in a cage with the blade of an outer leaf projecting into a second cage. In the second cage were 50 infective males which had undergone a fast of $3\frac{1}{2}$ hours. These could feed on the blade of the outer leaf but not on its petiole. In the narrow space between the two cages, the petiole was covered with cotton. At the end of the desired time, the petiole was cut off at the crown of the beet. The shortest time for the movement of the infective agent was one-half hour at a mean temperature of 103.5° F. through a petiole seven inches long. In a similar experiment, except that 25 infective males were used the pathogenic factor travelled $3\frac{1}{4}$ inches in one-half hour at a mean temperature of 102° F. Ten beets failed to develop curly leaf symptoms.

In another experiment using 25 infective males, the movement of the causative agent of curly leaf in the petiole at the end of one hour was as follows:

Petioles $4\frac{3}{4}$ and $5\frac{1}{2}$ inches long. Mean temperature 100.5° F.

Petioles of two beets $3\frac{1}{2}$ inches long. Mean temperature 94° F. Five beets failed to develop the disease.

Forty-two trials reducing the time to 15, 10 and 5 minutes gave negative results. The number of infective leafhoppers was increased, using from 100 to 500 insects. To insure feeding of as many as possible of the hoppers in such a short exposure of the leaf, the cages were covered with black sateen except on one side through which the light entered the cage. The blade projected in the cage toward the side through which the light entered, and large numbers of adults were induced to congregate on the blade.

CURLY LEAF TRANSMISSION FROM INFECTIVE TO NON-INFECTIVE BEET
LEAFHOPPERS ON VARIOUS LEAVES OF SUGAR BEET

In the first series of experiments an attempt was made to determine how soon the causative agent of curly leaf was transmitted from infective beet leafhoppers feeding on the outer or oldest leaves to non-infective hoppers on the inner or youngest leaves of a sugar beet. The outer leaves of a beet were projected into two cages, each containing 75 infective adults, while the inner leaves were enclosed in a third cage containing 150 non-infective males. The petioles of the outer leaves were enclosed in paraffine paper and were covered with sand and cotton at the crown of the beet. Twenty adults were removed daily for seven days from the cage enclosing the youngest leaves and were transferred to seven successive healthy beets. The disease was transmitted from infective adults feeding on the outer leaves to non-infective specimens on the inner leaves at the end of six days at a mean temperature of 87.7° F. The seventh beet also developed curly leaf symptoms. The original beet exposed to the influence of both infective and non-infective adults showed the transparent venation of curly leaf at the end of nine days.

In a similar experiment the disease was transmitted from infective adults feeding on the outer leaves to non-infective hoppers on the inner leaf at the end of 10 days at a mean temperature of 80.1° F. The original beet showed the first visible symptom of curly leaf at the end of nine days.

Negative results were obtained at the end of 8, 10 and 10 days when the feeding of the leafhoppers was reversed; i. e., when the infective adults were fed on the youngest leaves and the non-infective insects on the oldest leaves. The original beets had from 10 to 14 leaves.

A different method was used in determining curly leaf transmission from infective to non-infective beet leafhoppers on the outer and inner leaves of small beets, owing to the fact that the feeding of a large number

of hoppers killed the seedlings. A small leaf-cage containing six infective males was fastened to one of the first two outer leaves (Fig. 1) and another leaf-cage enclosing six non-infective males was attached to one of the inner or youngest leaves (Fig. 1) of a potted seedling having usually four true leaves. The beet was enclosed in a cage. This experiment was repeated 84 times. At the end of 1 to 4 days, the leaf-cage confining the six infected adults was removed, the specimens taking no

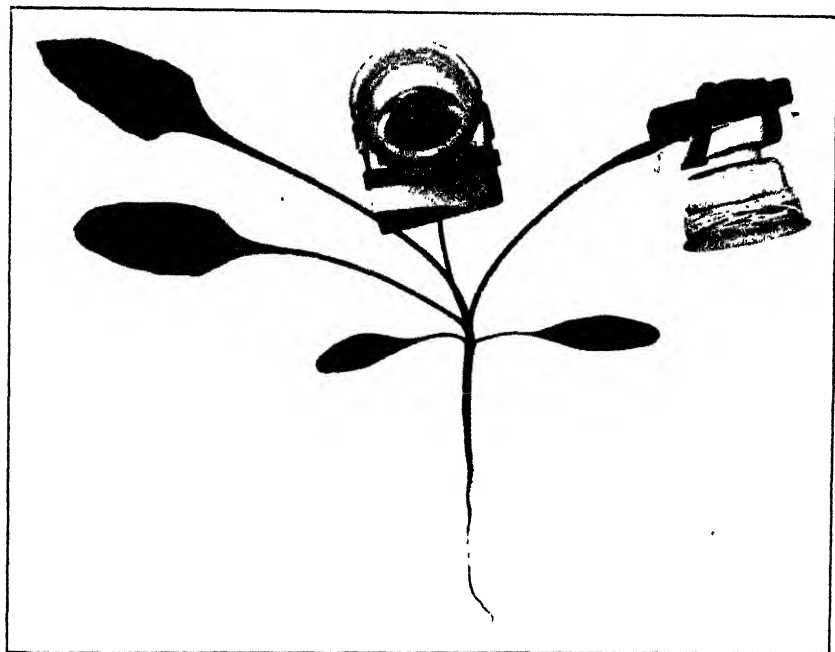


FIG. 1. Small leaf cages used for aphid experiments.

further part in the experiment. The leaf-cage containing the six non-infective males was removed at the end of 1 to 4 days and liberated in a cage enclosing a healthy beet. The disease was transmitted from infective males on the outer leaf to non-infective males on the inner leaf at the end of four days in 5 of 12 beets to which the males had been transferred. The temperature of the four days was as follows: maximum 107°F. ; minimum 56°F. ; and mean 79.8°F. Negative results were obtained at the end of 1 to 3 days with 72 beets.

Infective beet leafhoppers were allowed to feed on the inner or youngest leaf of the beet seedling while at the same time non-infective males

fed on one of the first two outer leaves. The non-infective males became infective at the end of two days, as was proved by transferring them to a healthy beet. The temperature of the two days was as follows; maximum 104° F.; minimum 50° F.; and mean 81.2° F.

The infective principle of curly leaf was transmitted from infective beet leafhoppers feeding on one of the first two outer leaves to non-infective males feeding on the opposite outer leaf at the end of two days at the following temperatures: maximum 108° F.; minimum 55° F.; and mean 81° F.

Two days were also required for the causative agent of curly leaf to be transmitted from infective adults feeding on a cotyledon to non-infective males feeding on an inner leaf and in a second experiment, from a cotyledon to one of the first two outer leaves. The temperatures of the two days in these experiments respectively was as follows: maximum 107° F., 102° F.; minimum 65° F., 60° F.; and mean 83.3° F., 79° F.

The period of two days required in most of the curly leaf transmission experiments from infective to non-infective beet leafhoppers feeding on various leaves of a sugar beet corresponds to the minimum incubation period of the infective principle in beet seedlings with 4 to 6 leaves including the two cotyledons. The cleared veinlets of curly leaf sometimes appear on the youngest leaf of beet seedlings at the end of two days. Beet leafhoppers, however, do not always become infective by feeding on beets showing this early symptom of the disease. This was demonstrated by cutting off the apparently healthy leaves which showed no visible symptom of curly leaf and allowing non-infective males to feed only on the leaf showing the transparent network of minute veins, and then transferring them to a healthy beet.

BET LEAFHOPPER INFECTIVE DURING ALL NYMPHAL STAGES

The beet leafhopper is capable of transmitting curly leaf during all nymphal stages. Twelve nymphs after hatching were fed upon a curly leaf beet during one day and then transferred to a healthy beet, which showed curly leaf symptoms nine days later. After each molt a different lot of 12 nymphs were fed for one day on blighted beets and they then transmitted the disease to healthy beets. During the process of the last molt, three non-infective adults were transferred to curly leaf beets for one day and the next day were confined in three cages, each enclosing a healthy beet. The three beets developed curly leaf.

According to Shaw (2) nymphs produce the symptoms of curly leaf

much more rapidly than do the adult insects, hence the nymphs are more virulent. There is such a wide variability as to the duration of the developmental period of curly leaf symptoms in beets of the same age, under the same conditions of temperature, humidity and sunshine, and infected by the same number of nymphs and adults, that we are hardly justified in stating that nymphs are more virulent than adults on the rate of curly leaf development.

An attempt was made to put to an experimental test Shaw's view that nymphs are more virulent than adults. A nymph upon hatching and a non-infective male after the last molt were confined in a cage enclosing a curly leaf beet upon which both fed for one day. The next day the nymph and male were put in separate cages. Each nymph and male was supplied with a healthy beet daily until the nymphs acquired the winged stage when the experiment was discontinued. The same experiment was repeated six times. The results are indicated in table 1.

TABLE 1—*Comparison of number of curly leaf beets produced by nymphal instars and males infective after last molt.*

Number of beets fed upon 1 day by each nymph	Number of curly leaf beets caused by each nymph	Percentage of curly leaf beets caused by each nymph	Number of beets fed upon 1 day by each male	Number of curly leaf beets caused by each male	Percentage of curly leaf beets caused by each male
33	4	12.1	33	0	0.0
34	2	5.8	34	10	29.4
34	6	17.6	34	1	2.7
37	6	16.2	37	6	16.2
37	7	18.6	37	9	24.3
38	9	23.6	38	13	34.2
—	—	—	—	—	—
213	34	15.9	213	39	18.3

There is no evidence from table 1 to show that nymphs are more virulent than adults. It is evident that the nymphs do not lose their infectivity during the process of molting.

BEEF LEAFHOPPER INFECTIVE DURING ENTIRE ADULT LIFE

Bonequet and Stahl (1) assert that the ability of the beet leafhopper to transmit curly leaf was lost in from 15 to 35 days if the insects were transferred daily to healthy beets.

An experiment somewhat similar to the one which Bonquet and Stahl (1) had performed was conducted. Eight infective first brood males which had completed all of the nymphal stages on a blighted beet, acquired the winged stage on April 19, and were confined singly in eight cages on this date. A healthy beet seedling with from 4 to 6 leaves was placed in each cage daily until the males died. Males were used instead of females to avoid egg deposition, since the beets were kept in insect-proof compartments until the symptoms of curly leaf developed. The following data concerning the largest and smallest number of blighted beets produced by two males are given rather than of the entire eight specimens. The maximum and minimum temperatures follow after each date on which the male transmitted curly leaf.

April 19/ 22, 109°, 50° F.; 20, 104°, 55° F.; 22, 100°, 56° F.; 25, 72°, 53° F.; 26, 107°, 52° F.; 27, 104°, 50° F.; 28, 106°, 50° F.; 29, 102°, 54° F.; May 2, 114°, 55° F.; 4, 102°, 58° F.; 6, 100°, 50° F.; 8, 100°, 45° F.; 9, 93°, 45° F.; 12, 104°, 52° F.; 13, 106°, 56° F.; 17, 82°, 55° F.; 18, 74°, 56° F.; 19, 74°, 54° F.; 20, 98°, 49° F.; 24, 112°, 50° F.; 25, 106°, 53° F.; 27, 110°, 59° F.; 28, 104°, 58° F.; 29, 104°, 58° F.; 30, 110°, 58° F.; June 2, 111°, 54° F.; 4, 112°, 60° F.; 5, 108°, 60° F.; 6, 104°, 64° F.; 7, 100°, 62° F.; 11, 92°, 59° F.; 15, 103°, 56° F.; 16, 104°, 57° F.; 18, 119°, 61° F.; 21, 120°, 57° F.; 23, 106°, 60° F.; 24, 110°, 60° F.; 28, 93°, 62° F.; July 4, 95°, 64° F.; 6, 88°, 62° F.; 13, 104°, 62° F.; 14, 104°, 58° F.; 15, 104°, 60° F.; 16, 92°, 62° F.; 27, 114°, 60° F.; 28, 96°, 58° F.; 29, 96°, 60° F.; 31, 112°, 60° F.; August 1, 87°, 58° F. Died August 3. Total 107 beets, 49 curly leaf beets or 45.7 per cent.

April 19/ 22, 109°, 50° F.; 20, 104°, 55° F.; 22, 100°, 56° F.; 28, 106°, 50° F.; May 2, 114°, 55° F.; 4, 102°, 58° F.; 22, 116°, 52° F.; 23, 103°, 51° F.; 28, 104°, 58° F.; June 20, 104°, 59° F.; 22, 110°, 58° F.; July 13, 104°, 62° F.; 14, 104°, 58° F.; 25, 110°, 56° F. Died August 1. Total 105 beets, 14 curly leaf beets or 13.3 per cent.

It is evident from the above figures that the males transmitted curly leaf at irregular intervals and under a wide range of temperature.

There is a marked variability as to the number of times a male, during its adult life, can transmit curly leaf when provided with a healthy beet daily as indicated in table 2. Temperature, humidity and sunshine were identical for the eight males used in this experiment.

The males usually transmitted curly leaf to fewer beets toward the end of their natural life. The interval between the last beet infected with the disease by each hopper and the death of the insect was in most cases less than the longest period elapsing between the infection of two successive beets as is shown in table 2.

TABLE 2—*Data on infectivity of beet leafhopper during adult life.*

Number of beets fed upon 1 day by each male	Number of curly leaf beets caused by each male	Percentage of curly leaf beets caused by each male	Longest period between two curly leaf infections (days)	Period between last curly leaf infection and death of male (days)
116	25	21.5	13	15
108	24	22.2	15	5
107	49	45.7	13	2
105	14	13.3	21	7
86	14	16.2	19	19
82	36	43.9	6	7
64	15	23.4	15	10
27	15	55.5	14	5
—	—	—	—	—
695	192	27.6	14.5	8.7

A comparative study was made of the number of curly leaf beets caused by each infective beet leafhopper which was provided with a healthy beet daily with the following experiments: (1) each infective male was allowed to feed alternating daily on a healthy and a diseased beet; (2) each infective male was supplied with a healthy beet at the end of every second day. Second brood males were employed which had fed during

TABLE 3—*Comparison of number of curly leaf beets caused by infective male beet leafhopper feeding on successive beets daily, for two days and alternating daily on healthy and curly leaf beets.*

Four infective males each provided with healthy beets daily			Four infective males each allowed to feed two days on each healthy beet			Three infective males each allowed to feed alternat- ing daily on healthy and diseased beets		
Healthy beets	Curly leaf beets		Healthy beets	Curly leaf beets		Healthy beets	Curly leaf beets	
No.	No.	%	No.	No.	%	No.	No.	%
86	28	32.5	64	14	21.8	21	7	33.3
66	23	34.8	40	14	35.0	18	7	38.8
55	24	43.6	30	16	53.3	15	5	33.3
52	18	34.6	21	4	19.0	—	—	—
—	—	—	—	—	—	—	—	—
259	93	35.9	155	48	30.9	54	19	35.1

all of the nymphal stages on blighted beets and passed through the last molt on June 1 to 2. Beet seedlings with 4 to 6 leaves were used. The results are indicated in table 3.

A glance at table 3 shows no marked differences in the average percentages in the first and third experiments.

In the next experiment 1, 2, 3, 4 and 5 infective males which had completed all of the nymphal stages on a blighted beet were confined in five cages in the greenhouse. A healthy beet was placed in each cage daily. When a leafhopper died, another was put into the cage, except the one containing a single specimen. The experiment extended over a period of 54 days from November 1 to December 24, 1920, and was discontinued when the single male died. The results follow:

One infective male transmitted curly leaf to 3 beets or 5.5 per cent in 54 days.

Two infective males transmitted curly leaf to 10 beets or 18.5 per cent in 54 days.

Three infective males transmitted curly leaf to 31 beets or 57.4 per cent in 54 days.

Four infective males transmitted curly leaf to 28 beets or 51.8 per cent in 54 days.

Five infective males transmitted curly leaf to 28 beets or 51.8 per cent in 54 days.

Mean maximum 78.9° F., mean minimum 61.7° F., mean 70.3° F., temperatures.

Two similar experiments were performed except that when a leafhopper died, another male was *not* put in the cage as in the preceding experiment. The first of these two experiments extended over a period of 134 days from April 1 to August 12; the second over a period of 114 days from April 15 to August 7, and both were discontinued when the last male died. The results are indicated in table 4.

An examination of Table 4 shows that a higher average percentage of curly leaf was transmitted by the males in the first experiment (33.5 per cent) than in the second experiment (21.6 per cent). When the number of leafhoppers was reduced to one, there were periods of 8, 20, 47 and 56 days in which no curly leaf was produced.

CONTAMINATION OF MOUTH-PARTS WITH *BACILLUS MORULANS*

Smith and Boncquet (3), Townsend (5) and Brown have found lesions or pockets containing bacteria in sugar beets affected with curly leaf but inoculations with pure cultures of these bacteria failed to produce

TABLE 4—Number and percentages of curly leaf beets caused by 1 to 5 infective male beet leafhoppers provided with a healthy beet daily in two experiments.

Dates 1921	No. of ♂♂	No. of beets	No. of curly leaf beets	Percentage of curly leaf beets	Dates 1921	No. of ♂♂	No. of beets	No. of curly leaf beets	Percentage of curly leaf beets
4/1-6/12	1	73	16	21.9	4/15-7/1	1	78	5	6.4
4/1-17	2	17	9	52.9	4/15-29	2	15	9	60.0
4/18-22	1	5	2	4.0	4/30-6/28	1	60	4	6.6
		22	11	50.0			75	13	17.3
4/1-4	3	4	3	75.0	4/15-5/16	3	32	12	37.5
4/5-5/2	2	28	11	39.2	5/17-6/21	2	36	5	13.8
5/3-6/5	1	34	3	8.8	6/22-8/7	1	47	0	00.0
		66	17	25.7			115	17	14.7
4/1-5/31	4	61	42	68.8	4/15-5/20	4	36	20	55.5
6/1-15	3	15	4	26.6					
6/16-6/17	2	2	0	00.0	5/21-31	2	11	2	18.1
6/18-8/12	1	56	0	00.0	6/1-7/8	1	38	4	10.5
		134	46	34.3			85	26	30.5
4/1-7	5	7	7	100.0	4/15-22	5	8	8	100.0
4/8-17	4	10	8	80.0	4/23-5/25	4	33	17	51.5
4/18-5/26	3	39	17	43.5	5/26-31	3	6	2	3.3
5/27-6/14	2	19	5	2.6	6/1-24	2	24	8	3.3
6/15-22	1	8	0	0.0	6/25-7/14	1	20	0	0.0
		83	37	44.5			91	35	38.4

the disease. To determine whether the beet leafhopper increases the virulence of *Bacillus morulans* as suggested by Smith and Bonquet (3) the mouth-parts were contaminated with this bacterium. The bacteria were rubbed on the mouth-parts of torpid non-infective hoppers with sterilized camel's hair brushes. The adults were put into a torpid condition by chilling them in a phial embedded in chipped ice. The insects had been previously fasted for a period of 6 to 8 hours with the hope that they would feed and inject the bacteria with the saliva into the beet foliage shortly after overcoming their numbness. This experiment was repeated with 141 adults, but not a single case of curly leaf developed.

Non-infective beet leafhoppers were allowed to feed on beet seedlings with a portion of a leaf covered with *B. morulans*,¹ so that in making the

¹ Miss E. H. Smith prepared the cultures of *B. morulans* which were determined by Professor R. E. Smith, Department of Plant Pathology, University of California.

feeding puncture it was presumed that the mouth-parts would become contaminated and some of the bacteria would be injected into the leaf. The hoppers, which had been fasted from 6 to 8 hours, were confined in small leaf-cages (Fig. 1) enclosing the bacteria. This experiment was conducted with 190 nymphs and 22 adults, using 61 beet seedlings but no curly leaf developed.

SUMMARY

Juice pressed from the leaves and roots of curly leaf beets when inoculated into the crown of healthy beets caused typical curly leaf symptom in nine of one hundred beets. The period from the date of inoculation until the earliest visible symptom of curly leaf developed varied from 12 to 39 days. Non-infective beet leafhoppers, when allowed to feed on the inoculated beets after curly leaf developed, transmitted the disease to healthy beets, the earliest symptom appeared in from 2 to 13 days.

The causative agent of curly leaf is generally distributed in the foliage and beet root.

Field and laboratory experiments demonstrate, beyond any question of doubt, that curly leaf is not transmitted through the soil or from beet to beet.

The shortest time required for the infective principle of curly leaf to travel through a beet petiole seven inches long was one-half hour at a mean temperature of 103.5° F.

Four¹ days were required for the pathogenic factor to be transmitted from infective adults feeding on one of the first two outer leaves to non-infective males feeding on the inner or youngest leaf of a beet seedling, as was proved by transferring the latter to a healthy beet. Two days were required for the inciting agent of curly leaf to be transmitted from infective leafhoppers feeding on the inner leaf to non-infective males on the outer leaf of a beet seedling, also from one of the first two outer leaves to the opposite outer leaf and from one cotyledon to the inner leaf and from one cotyledon to one of the first pair of outer leaves.

Infective beet leafhoppers retained their infectivity during all of the nymphal stages, after each molt, and during the entire adult life.

Non-infective beet leafhoppers which had been fasted and then the mouth-parts contaminated with *Bacillus morulans* isolated from curly

¹ Since sending this manuscript to the editor, the period of four days has been reduced to two days in 1 of 24 experiments. The temperatures of the two days was as follows: maximum 105° F.; minimum 58° F.; and mean 81° F.

leaf beets or when allowed to puncture the bacteria into the tissue, rubbed on a portion of a beet leaf, failed to transmit the disease.

LITERATURE CITED

- (1) BONCQUET, P. A. AND C. F. STAHL. Wild vegetation as a source of curly-top infection of sugar beets. Jour. Econ. Ent. 10: 392-397. Pl. 17-18. 1917.
- (2) SHAW, H. B. The curly-top of sugar beets. U. S. Dept. Agric., Bur. Plant Industry Bul. 181. p. 1-46. 9 pl., 9 fig. 1910. Bibliography, p. 37-40.
- (3) SMITH, R. E. AND P. A. BONCQUET. New light on curly-top of the sugar beet. Phytopath. 5: 103-107. 3 fig. 1915.
- (4) ————. Connection of a bacterial organism with curly leaf of the sugar beet. Phytopath. 5: 335-342. Pl. 17, 1 fig. 1915.
- (5) TOWNSEND, C. O. Sugar beet curly-top. Phytopath. 5: 282. 1915.

NOTES ON THE CLIMATIC CONDITIONS INFLUENCING THE 1923 EPIDEMIC OF STEM RUST ON WHEAT IN ILLINOIS

L. R. TEHON AND P. A. YOUNG

WITH ONE FIGURE IN THE TEXT

Stem rust, caused by *Puccinia graminis* Pers., is prevalent in Illinois every season, but seldom in quantities sufficient to influence seriously the wheat yield of the state. The importance of this disease in more northerly situated states has, however, led to extensive epidemiological studies on the origin and spread of northern and southern infections.

The backward spring of 1923 with its attendant unusual weather provided conditions which appear to have been unusually suitable for the development of stem rust in Illinois. The development of the rust was kept under observation by the field workers of the Natural History Survey from the date of its first known appearance until the harvesting of the crop. Pertinent observations are presented here in connection with climatological data for the purpose of pointing out the influence of temperature and moisture in the development of an epidemic extending over a wide area.

Stem rust was first seen on wheat, June 4, in a 20-acre field of Red Wave located in the northwest corner of Jackson County. A single culm was found infected. Rust pustules on this culm occupied 50 per cent of the possible maximum culm surface (by the scale of U. S. Office of Cereal Investigations). The infected culm was located well in from the edge of the field.

On June 7 a few isolated groups of rusted culms were found in an 80-acre field of Fulcaster in Bond County. On these culms the rust pustules occupied 70 per cent of the possible maximum. A similar condition was seen June 12 in a 10-acre field of Fulz in Franklin County, and on June 14 two fields were seen, one in Hamilton and one in White County, where culms showed respectively 80 per cent and 100 per cent pustule involvement.

It is typical of these early observations that only a very few culms in any one spot showed infection, and that these foci were located well within the field, were well isolated from each other, and showed uniformly high percentages of pustule involvement. All observable facts pointed to the conclusion that these were primary infections of recent development.

There is no definite information as to the source of the inoculum for these infections. In the case of the first observation, four shrubs of common barberry were located 6 rods from the field, but a careful examination revealed no aecia. It may be supposed that the inoculum was furnished by uredinia overwintering in the field or on grasses along the roads or fence lines. The possibility of uredospores blowing up from the southwest or of accidiospores traveling from the north is limited by the fact that the prevailing wind direction in this region during the month of May and during early June was easterly.

Beginning June 16, dissemination of the rust from original foci of infection became apparent. On that date infection on all culms within a small area in each of three 10-acre fields of Fulz was observed in Randolph County. On June 18, thirteen fields in Monroe County including about 160 acres showed isolated spots of rust infection comprising a number of plants and having areas of pustule involvement varying from 5 to 50 per cent, the lesser percentages apparently being infections produced by uredospores shed from the stalks showing higher degrees of pustule involvement.

By June 22 the per cent of infected plants generally had become nearly 100, but the original foci of infection could still be definitely located. Six fields in Morgan County showed large spots of infection with pustule involvement on the edges of 5 per cent, and toward the center of 35 per cent. Another field showed a general infection with an average pustule involvement of 10 per cent but with occasional spots of 70 per cent. On the 23rd in Adams County and on the 27th in Calhoun County similar conditions were seen.

The foregoing examples typify the progress of rust development as seen in other localities. In general, it appears that small and isolated foci of severe rust infection developed as a result of the presence of infectious material whose source was not determinable. Invariably these foci were severe infections showing large percentages of pustule involvement. From these foci, by degrees, the infection of entire fields was accomplished, the secondary and succeeding infections being gradually less severe and exhibiting correspondingly smaller percentages of pustule involvement.

The lessened severity of secondary infections may be attributed in part to the increasing maturity of the wheat plants (Stakman, E. C. and F. J. Piemeisel. Biologic forms of *Puccinia graminis* on cereals and grasses. Jour. Agr. Res. 10: 431-432. 1917).

Moisture as a factor in the development of primary infections is im-

portant and under field conditions the necessary presence of moisture is definitely related to precipitation. There is an apparent relation between periods of precipitation (U. S. Weather Bureau, Climatological data for Illinois) and the occurrence of the infections recorded above.

For ten days previous to the finding of the first infection of the season in Jackson County, there had been rain in that district on all but one day. Obviously, the total amount of rain for the ten-day period is not important, but the fact that measurable amounts were recorded on seven of the ten days and an observable amount on two other days is indicative of the existence of moisture conditions suitable for spore germination and host infection throughout practically the whole of that period.

In the case of the primary infection in Bond County, during thirteen days previous rain had fallen on all but three days and for a period of nine consecutive days there had been an appreciable amount each day. These nine days were followed by three days of no rain and a fourth day of hard rain, none of which may be considered to have influenced the inception of the infection. Favorable moisture conditions in this and the previous case coincide rather definitely as to dates.

Although the infections in Franklin, Hamilton and White Counties were found five and seven days later than the above their appearance characterizes them as similar to the first two found. No certainty as to the date infection took place obtains, but it is reasonable to point out that, during the period of precipitations noted in the first two counties, smaller quantities had fallen in the last three counties, over a shorter and generally earlier period. The seven days immediately previous to the finding of the infection in Franklin County had, however, been initiated with precipitations over three consecutive days sufficient in amount to provide favorable conditions for spore germination.

When favorable moisture conditions obtain, there must exist at the same time proper temperatures for spore germinations and host infection. A comparison of temperature (maximum and minimum) and precipitation previous to the date of the finding of the infections is given in the following tables and discussions.

The first primary infection found (Jackson County, June 4) affords the best opportunity for speculation as to the influence of climate on the inception and development of infection. The attendant weather conditions were as follows:

	May 25	26	27	28	29	30	31	June 1	2	3	4
Precipitation	.08	.03	.02	.03	.02	T		T	.4	.02	
Temperature	74	74	82	87	86	87	88	83	85	86	87
	61	60	61	60	61	61	62	64	65	63	63

The ten-day period of rain previous to the finding of this infection was initiated by two days of unusually low maximum temperature. On the third day there was an increase in maximum temperature of eight degrees and on the fourth of five more degrees. This high maximum temperature was maintained with fair constancy during the remaining seven days. During the entire period the minimum temperature was fairly constant.

When the time necessary for development of infection is considered it is not likely that either the moisture or temperature during the last four days could have influenced infection. The first two days with their low temperatures were probably not conducive to spore germination. This leaves a period beginning May 27 and ending May 31 during which germination and infection could have taken place. The mean temperature on May 27 was 71.5° or an increase of 4.5° over the mean temperature of the day preceding. On the 28th the mean temperature of 73.5° represents a further increase of 2° . The average mean temperature for the five days from May 27 to May 31 was 73.5° and the greatest departure of the mean on any one day below this average was 2° while the greatest departure above was 1.5° .

The climatological conditions attending a thirteen-day period previous to the finding of the second primary infection (Bond County, June 7) coincide generally both as to points of time and conditions with those attending the first primary infection, as may be observed from an inspection of the following:

	May 25	26	27	28	29	30	31	June 1	2	3	4	5	6	7
Precipitation	.13	.11	.10	.40	.17	.16	.06	T	82	0	0	0	.71	0
Temperature	73	74	76	72	77	80	81	77	82	83	84	80	—	81
	58	62	61	63	64	63	62	65	67	63	64	68	66	63

There was, however, generally a greater amount of precipitation, and, from the fifth to the thirteenth day preceding, no day passed without some precipitation. The first five days were characterized by rather low maximum temperatures. On the sixth day the maximum temperature rose 3° and was maintained at this point or above on all but one of the succeeding days. The minimum temperature was fairly constant throughout the period, averaging 63.5° . The greatest departure above the minimum average was 3.5° and below 5.5° . The average departure above was 2° and below 1.6° .

On May 30 the mean temperature was 71.5° , showing an increase of 1° over the day previous and of 3.5° over the average mean temperature for the five preceding days. During the five days from May 30 to June 3

the average mean temperature was 72.3° . The greatest departure of the mean above on any one day was 2.2° and below 1.3° .

A noteworthy coincidence is found in the fact that a mean temperature of 71.5° occurred in Bond County three days after it had occurred in Jackson County and that the first primary infection was found in Bond County three days after the first infection was found in Jackson County. Any significance that may be attached to this coincidence of elapsed time must find its justification in the fact that men were examining wheat fields in these two regions for several days before stem rust infections were found. The coincidence of a mean temperature of 71.5° may be considered as indicating the probable optimum for infection under field conditions.

The primary infection found in Franklin, Hamilton and White Counties must be considered in connection with the same climatological data since the point nearest to the infections where climatological data was recorded is at McLeansboro in Hamilton County. The consideration of these infections is further complicated by the fact that they were found in the first fields visited in those counties. The date of finding probably is not the date of first appearance. However, a consideration of the precipitation and temperature may serve to indicate when spore germination and host infection might have taken place. The McLeansboro records are as follows:

May						25	26	27	28	29	30	31
Precipitation						.18	.03	.17	.07		.24	.17
Temperature						73	75	79	81	86	84	88
						64	60	62	68	61	63	63
June	1	2	3	4	5	6	7	8	9	10	11	12
Precipitation					.03	.41	.04			.76	2.55	.12
Temperature	85	88	90	90	90	84	87	80	75	70	79	74
	64	64	62	62	65	66	64	57	56	58	66	61

Because of the uncertainty involved in the field observations as to the exact age of the rust pustules found in these counties, the data given above are shown from May 25 in order to furnish precipitation and temperature records covering the same days in this region as in the regions hitherto spoken of. The need for this is emphasized by the fact that all these infections lie in approximate relation so far as latitude is concerned.

The first three days of this period were initiated with comparatively low maximum temperatures, and an average mean temperature of 68.8° . The maximum temperature during the five following days was notice-

ably higher, ranging from 81° to 88° , and with a correspondingly higher average mean temperature of 74.3° . During this entire period there was sufficient precipitation to provide moisture conditions favorable for spore germination, although a comparison with the other regions shows that in these cases the precipitation was more spasmodic though greater in quantity.

It is impossible to surmise in any satisfactory way as to the influence of this period upon the inception of infection in this territory. It is, however, noteworthy that from June 5 to June 7 there was precipitation on each day. This period was preceded by four days and followed by two days when no precipitation fell. The maximum temperature during these three days of precipitation ranged from 84° to 90° , and the average mean temperature was 76° . The beginning of this rainy period was just seven days prior to the finding of the rust infection in Franklin County, and is comparable to eight days in the case of the Jackson and Bond County infections.

An inspection of the data on precipitation and temperature accompanying secondary and later infections observed in ten counties appears in general to conform with the above observations on the primary infections; and it may be seen that excellent conditions for the development of secondary and later infection were provided from time to time and in general over periods corresponding rather definitely as to dates, yet allowing sufficient latitude to account for later occurrence of infection and varying degrees of infection in the several instances.

The first observations of the occurrence of evident secondary infection (in Randolph County, June 16) was preceded by the following moisture and temperature conditions:

June	9	10	11	12	13	14	15	16
Precipitation	.45	.36	.87	.01			.44	
Temperature	80	71	81	74	88	91	81	85
	58	59	67	62	55	57	63	62

On each of the four days from June 9 to 12 precipitation fell and very likely provided favorable moisture conditions. On the 9th and again on the 11th the maximum temperature rose to 80° or above and on the 11th the mean temperature was 74° .

It may be seen that favorable conditions for spore germination and host infection both as to moisture and temperature occurred from five to seven days previous to the finding of the secondary infection.

This condition is duplicated generally in the case of the nine other counties in which observations were made. Under the presumption

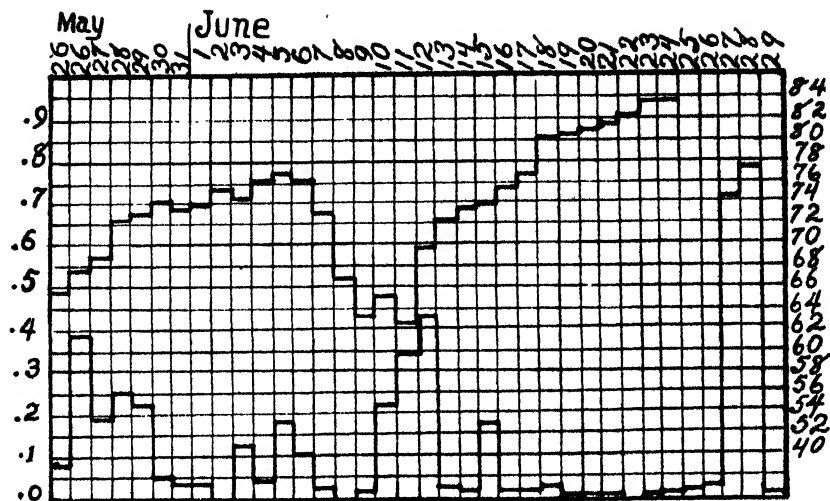


FIG. 1. Average mean temperature and average precipitation in fifteen counties of central and southern Illinois during late May and June.

Upper line: Average mean temperature. Temperature scale at the right.

Lower line: Average precipitation. Precipitation scale at the left.

that primary infection occurred in all cases either from about May 25 to 29 or June 2 to 6, subsequent periods of favorable spore-germination conditions may be considered as accounting for subsequent infections, whether secondary or later. The following chart showing precipitation and temperature summarized for the whole set of observations and the time when infections were found, will indicate, in terms of the above interpretations, the probable period of primary, secondary and later infections so far as they may be thought to have any dependence upon climatological conditions.

NOTES ON CRANBERRY FUNGI IN MASSACHUSETTS

NEIL E. STEVENS

The rots of cranberries (*Vaccinium macrocarpum*) caused by various fungi show, with but one or two exceptions, no constantly marked and characteristic differences. In order to determine the causal organism with any degree of accuracy it is necessary to make cultures from the tissues of the rotten berries. In the course of the studies of cranberry diseases¹ made under the general direction of Dr. C. L. Shear more than six thousand cultures from Massachusetts berries alone have fruited and been identified. These cultures have been largely incidental to the work on the diseases of cranberries carried on jointly by the Massachusetts Agricultural Experiment Station and the United States Bureau of Plant Industry. Over five thousand of these cultures have been made since the fall of 1916, at which time attention was directed especially to the rots which develop after the berries are picked. During this period much of the culture work has been handled during different seasons by Miss A. M. Beekwith, Miss M. S. Wilcox, B. A. Rudolph, Robert Jordan, and W. H. Sawyer, Jr. The storage and shipping experiments have been planned and carried out jointly by Dr. H. J. Franklin, Superintendent of the Cranberry substation at East Wareham, and the writer. Dr. Franklin has at all times placed the facilities of the state cranberry bog and laboratory at the disposal of those engaged in the mycological work, with the result that the data available are drawn largely from the region within twenty miles of East Wareham, and may not exactly represent the Massachusetts cranberry area as a whole. Notwithstanding this limitation, the work here summarized represents a more intensive study of the fungi causing decay than has been made of any other berry, and may thus justify brief presentation.

RELATIVE IMPORTANCE OF DIFFERENT ROT FUNGI

Fungi belonging to at least twenty-five genera have been found in cultures from decayed or sound cranberries. They differ greatly, however, in their relative abundance. Several fungi have been isolated only once or twice, while more than one-third of the berries from which cultures were made yielded the end-rot fungus, *Fusicoccum putrefaciens*.

¹ Cranberry diseases and their control. U. S. Dept. Agric., Farmers' Bulletin 1031, 1920, (and earlier papers by the same author).

In table 1 are listed the fungi which have been found more than ten times in the tissue of rotten or immature cranberries from Massachusetts, with the number of times they have occurred in the total of 6617 cultures which were identified. The second column gives the number of times each fungus has occurred in the cultures made from the tissue of rotten berries, while the third column gives the number of times each has occurred in the series of cultures made from freshly picked, immature berries.

TABLE 1—*More important fungi found in tissue of decayed cranberries from Massachusetts 1910 to 1922, and of green berries 1921 to 1923.*

Name of fungus	Number of times found in 5412 cultures from decayed berries.	Number of times found in 1205 cultures from green berries.
<i>Fusicoccum putrefaciens</i> Shear (causing end-rot)	2209	108
<i>Glomerella cingulata vaccinii</i> Shear. (causing bitter-rot)	1323	126
<i>Phomopsis</i> sp.	762	19
<i>Sporonema oxycocci</i> Shear	312	16
<i>Guignardia vaccinii</i> Shear (causing early-rot)	225	202
<i>Penicillium</i> sps.	204	183
<i>Dematium</i> sp.	158	225
<i>Pestalozzia guepini vaccinii</i> Shear	97	54
<i>Acanthorhynchus vaccinii</i> Shear (causing blotch-rot)	45	10
<i>Alternaria</i> sp.	15	159

In comparing the figures given in table 1, it should be borne in mind that the results of work on decayed berries cover a period of fourteen years and involve over five thousand cultures, whereas the work on green berries, which will be discussed in greater detail later, involves only about twelve hundred berries and is confined to the last three years. The results, however, plainly indicate that fungi of several genera, such as *Dematium* and *Alternaria*, are of more frequent occurrence in green berries on the vines than their importance as storage rots would seem to indicate. The high number of *Penicillium* cultures may well be due, in part, to contaminations.

EFFECT OF STORAGE TEMPERATURES ON THE DEVELOPMENT OF DIFFERENT FUNGI

While the data given in column 2 of table 1 may be taken as indicating the relative importance of the different fungi under average storage

conditions in Massachusetts it is evident that their abundance in any given case varies greatly and depends to some extent on the storage temperature. The effect of storage temperature is clearly shown by tests carried out in the fall of 1921 and 1922. In each test about a peck of sound berries from each of three different bogs were carefully sorted out by hand. This sample was then divided into two equal parts, one of which was stored in a ventilated crate at a temperature of approximately 0° C. while the other was stored in a similar container at a temperature varying from 15° C. to 20° C. In both seasons the storage test began in October and lasted four months. The results are given in table 2.

TABLE 2—More important fungi found in berries which had decayed during temperature storage tests, expressed as per cent of total spoiled berries from which cultures were made

Name of fungus	Developed in storage at	Developed in storage at
	0° C.	15°-20° C.
<i>Fusicoccum putrefaciens</i>	55.4	34.8
<i>Glomerella cingulata vaccinii</i>	2.0	14.0
<i>Guignardia vaccinii</i>	0.3	8.0
<i>Acanthorhynchus vaccinii</i>	0	3.7
Sterile	20.8	7.4

It is evident from these tests that the growth of *Fusicoccum putrefaciens* is not inhibited at temperatures near zero centigrade while the growth of such common rot fungi as *Guignardia vaccinii* and *Acanthorhynchus vaccinii* is practically stopped. Such a result might have been anticipated from their temperature relations as determined in pure culture.

TIME OF DEVELOPMENT OF FUNGI IN STORAGE

The difference in the temperature relations of the various rot fungi does not seem to account for the fact, demonstrated by Rudolph and Franklin¹ that different rot fungi tend to develop at different times in storage. In this careful piece of work it was clearly shown that under the conditions of the experiment in 1916 and 1917 such fungi as *Glomerella cingulata* and *Phomopsis* sp. predominated among those berries which decayed during the early part of the storage season while *Fusicoccum putrefaciens* was by far the most abundant organism in those berries which decayed later in the season. This relation held even though the

¹ Relative prevalence of fungi causing rots of cranberries at different periods during the storage season. Mass. Exp. Station Bul. 198: 88-92. 1920.

berries were stored at a uniform temperature of 20° C. The delay in the development of these fungi is all the harder to explain in view of the fact, demonstrated by the culture work of the last three years, that infection by these storage rot fungi often occurs early in the development of the berry.

TIME OF INFECTION OF CRANBERRIES BY FUNGI

That the rot producing fungi are either actually in the berry or so closely attached as not to be removed or injured by severe sterilization seems to be clearly demonstrated by series of cultures made in Massachusetts during the summers of 1921, 1922 and 1923. This work, which was planned to obtain information as to the prevalence and distribution of fungi on green berries, was carried out as follows. Beginning as early in July as the petals were shed, twenty or more berries were selected every week from each of several bogs and sterilized by soaking in a 1 to 1000 solution of mercuric-bichloride in seventy per cent alcohol, for five to ten minutes and then washing in sterile distilled water. They were then placed in sterile tubes of corn meal agar and held at room temperature.

The outstanding results of this work are that a large portion of the berries were found to be infected early in the season, that the proportion of infected berries did not increase greatly as the season advanced, and that most of the important fungi, even those that develop late, were found to be present early in the season. These results, which are summarised in tables 3 and 4, should be considered as applying only to the region and for the years in which the work was done.

TABLE 3—*Earliest dates on which various important rot fungi were found in green cranberries¹ in Massachusetts.*

Name of fungus	1921	1922	1923
<i>Fusicoccum putrefaciens</i>	July 13	July 6	July 18
<i>Glomerella cingulata vaccinii</i>	" 16	" 12	
<i>Phomopsis</i> sp.	August 2	" 6	
<i>Sporonema orycoeci</i>	July 21	" 6	July 19
<i>Guignardia vaccinii</i>	" 26	" 6	" 12
<i>Penicillium</i> sps.	" 13	" 6	" 11
<i>Dematium</i> sp.	" 13	" 6	" 11
<i>Pestalotzia guepini vaccinii</i>	" 16	" 12	" 19
<i>Acanthorhynchus vaccinii</i>	" 26		
<i>Altaria</i> sp.	" 13	" 6	" 18

¹ In explanation of the difference in the time of appearance of the fungi it should be stated that the spring of 1922 was unusually early and warm.

TABLE 4—*Number of immature cranberries from which fungi developed in culture, expressed as per cent of total number of berries cultured.*

Date 1922	Per cent infected	Date 1923	Per cent infected
July 6	60		
" 12	48		
" 19	33	July 18	35
" 26	61	" 25	48
August 2	51	August 1	70
" 9	56	" 8	81
" 15	64	" 15	56
" 23	45	" 22	48
" 29	61		

PLACE OF INFECTION

A series of cultures made during 1922 and 1923 by sterilizing berries as described above and then cutting them in half with a sterile scalpel and culturing the halves separately shows, as might be expected, that the blossom end of the berry is much more likely to be infected by fungi than the stem end. Of a total of 150 berries cultured in 1922, 100 of the stem ends were sterile and only 53 of the blossom ends. In 1923 berries were sterilized and the stem and blossom ends cut off with a sterile scalpel. The three parts of the berry were then cultured separately. Out of a total of 120 such cultures, fungi developed from 55 per cent of the blossom ends, while fungi developed from only 12 per cent of the stem ends and middle portions.

Such fungi as *Alternaria*, *Dematium* and *Fusicoccum* were decidedly more abundant on the blossom end, while *Guignardia* was equally abundant in cultures from either end. In one case three different fungi were isolated from the blossom end of a single berry.

OCCURRENCE OF FUNGI IN DIFFERENT VARIETIES

Most of the culture work in Massachusetts has been done on the two principal commercial varieties of that region, Early Blacks, and Howes. All the fungi listed in the tables have been found on both these varieties, and most of them have been found also on McFarlins and Centenials.

DISTRIBUTION OF CRANBERRY ROT FUNGI BY FLOODING WATER

The injury to cranberry buds and blossoms which has occasionally occurred in Massachusetts during the June reflow led to a study of the

fungi found on cranberry buds and tips with special reference to the conditions before and after the vines were submerged. So far as relates to flooding injury the results have been negative. While, as might be expected, fungi are present on buds that have been injured by flooding, the fungi are not markedly more abundant, nor of different kinds than are found on normal flowers which have survived the flooding. Fungi apparently play little if any part in the so called "water injury."

These culture studies have, however, brought out the fact that the flooding water acts as a carrier of fungous spores, probably by bringing them up from the trash on the bottom or about the sides of the bog. The evidence on this point was secured by collecting tips bearing flower buds from various bogs just before the June reflow, and placing them on sterile culture media after sterilizing as described for the berries. As soon as possible after the flowage water was removed a similar set was taken from near the same place and treated in the same way. The results are given in table 5.

TABLE 5—Results of cultures from cranberry tips taken before and after the June reflow. Averages of cultures from four different bogs each season.

Year	Per cent infected by fungi before flooding	Per cent infected by fungi after flooding
1922	35	67
1923	14	77

That the results of 1923 are more striking than those of 1922 is perhaps due in part to the fact that the technique used was somewhat improved, and in part to the cold spring of 1923. That the difference between the first set of cultures and the second in both years is directly due to the effect of the flooding water seems to be proven by the fact that no such difference is found in tips taken at similar periods from bogs which have not been reflowed.

OCCURRENCE OF THE SAME FUNGI IN OTHER CRANBERRY GROWING SECTIONS

While it should be clearly understood that the data here presented are derived wholly from observations made in Massachusetts and the conclusions apply only to that region, the fungi are widely distributed. Some of them have been found, not only in the region of commercial cranberry culture where they might easily have been carried in shipments of vines, but outside those areas on wild vines. Of the fungi listed in table 1, *Fusicoccum putrefaciens*, *Acanthorhynchus vaccinii*, and

Phomopsis sp. have been found in New Jersey, Wisconsin, the cranberry region of the Pacific Coast, in Maine, and in North Carolina. *Glomerella cingulata vaccinii*, *Guignardia vaccinii*, *Dematium* sp. and *Pestalozzia guepini vaccinii* have been found in New Jersey, Wisconsin, on the Pacific Coast, and in North Carolina. *Sporonema oxycocci* has been found in New Jersey, Wisconsin, on the Pacific Coast, and in Maine; and *Alternaria* sp. and *Penicillium* sps. in New Jersey, Wisconsin, and on the Pacific Coast. *F. putrefaciens* and *A. vaccinii* have also been collected in Alaska on *Vaccinium oxycoccus* and *V. Vitis-Idaea*.

CROP INJURY RESULTING FROM MAGNESIUM OXIDE DUST

F. J. SIEVERS

WITH ONE FIGURE IN THE TEXT

Magnesium carbonate, when properly treated, finds, besides its many other uses in the industries, a strong demand as a lining for furnaces where basic ores are smelted. Large deposits of native magnesite, MgCO_3 , are found in central Europe and these furnished most of our supply before the war. When, however, during the war an embargo was declared on this European product, there was an immediate interest in developing our own previously discovered magnesite resources. In eastern Washington is located a large deposit of magnesite rock of a very high percentage purity and this was mined, processed in newly constructed roasters and put on the market. In the manufacturing process the original rock is finely ground and mixed with a small amount of iron oxide and then calcined, resulting in a granular product referred to on the market as "dead burn" magnesite. This calcining is carried on at about 3900°F . in slightly inclined revolving cylindrical furnaces that are fed at the base with pulverized coal for fuel, with the result that much of the finely ground material after having been converted by this intense heat into the form of magnesium oxide is carried out through the stacks together with the smoke and large volumes of carbon dioxide gas, later to become deposited as a layer on the surrounding agricultural land. Due to the vigorous operation of the plant induced by wartime pressure although active only for a few years, the deposition of dust was sufficient to have a pronounced effect on the development of agricultural crops grown on soil in close proximity. At the time the plant discontinued operation a few years ago, this deposit, with its greatest thickness of somewhat more than an inch near the plant, was sufficiently extensive to be easily evident at distances of one and one-half miles to leeward.

The roaster is located in a valley bounded on the east and west by comparatively prominent mountain ranges and, due to the influence of this topography on the direction of air currents, even though located in the region of the prevailing westerlies, leeward here is both north and south of the source of the dust. With the magnesite plant as a center, the area over which crops were detrimentally affected was in the shape of an oval having approximately one mile and three miles, respectively, as its short and long axis.

The precipitation in this comparatively level, fertile and low lying valley, drained by the Colville River meandering through it, is limited to an average of about eighteen inches per annum, but this moisture supply is supplemented by sub-irrigation and surface run off from the surrounding uplands, which receive a slightly heavier annual rainfall. There has been little opportunity for loss of plant food through leaching, and consequently the soils contain large amounts of soluble salts, in some cases enough so that there were slight evidences of alkali, and practically all soils in the area were alkaline in reaction before the magnesite plant began operations. This alkalinity, being slight in amount or intensity, caused sufficient concentration of the soil solution to have a beneficial effect in the soil's productiveness. Soon after this deposition of magnesium oxide dust took place, however, injurious effects were noticeable on the crops. This was to be expected when one realizes that the deposited magnesia dust although only slightly soluble tended soon to increase the concentration of the soil solution or at least increase its toxicity to a point where it was no longer optimum for crop production. There apparently was a physical as well as a chemical, and no doubt also a pronounced toxic effect. The crust that accumulated on lands close to the plant from the time winter wheat was seeded up to the time that the plants should have appeared above the ground was of the consistency of mortar and sufficiently thick and impervious to make penetration by most plants impossible. The shoots that failed to penetrate this crust became elongated to a point where the energy in the seed was expended and then the plants died. Those plants that did get through soon took on a brownish yellow coloration at the tips of the leaves, and upon close examination it developed that consistent with plant conditions commonly found on alkali soil, practically their entire root system had been killed or corroded to the extent that there was no longer sufficient contact with the soil to furnish the necessary plant food or the foothold essential to hold the plants erect. Furthermore it is a common experience that within the injured area the detrimental effect of the magnesium is not nearly as pronounced in the early part of the growing season when the soil contains a high percentage of moisture and the soil solution is less concentrated. Various attempts to grow the small grain or grass crops to which this region is best adapted, failed for several years, and these failures were and are still decidedly pronounced close to the plant even after attempts had been made to overcome the difficulty by soil treatment with fertilizers, amendments and also irrigation water. At the distance of a mile or more, where there was still evidence

of the deposit, the injury was never as pronounced nor was it felt for as long a period. In some cases along the margin of the injured area where the deposit was only slight, it seemed to have even a beneficial effect on plant growth in which respect the conditions were similar to those ordinarily surrounding an alkali spot in irrigated regions.

To obtain all detailed information having a definite bearing on this subject, because of its importance to the magnesite industry and its relation to the use of magnesium carbonate or other compounds containing magnesium for soil treatment, a thorough investigation was planned by the author.

Field conditions were thoroughly examined and a record made of the influence of magnesium on plant development. Analyses for magnesium were made of representative soil samples carefully selected at various distances from the plant, soil from the area under consideration was taken to the plant house, where plants were grown on it under controlled conditions, and a fairly complete history of cropping experiences in the field was maintained.

The field area affected is quite diversified as regards soil type. It is comparatively common to find peat and muck adjacent to heavy silt or clayey loam. In such cases the crop injury from the magnesium deposit was always most pronounced on the peat and muck soils, which, because of their high organic matter content, were always lighter in volume weight. The difference in volume weight, which varied all the way from one million to three and a half million pounds per acre foot, has, no doubt, a decided bearing on the effect of magnesium, because on a percentage basis, even where the deposit was uniform, the concentration per unit of volume of soil in one case will be three and one-half times as great as in the other. This condition was taken into consideration in all chemical analyses of soil and subsoil and all results were calculated on the basis of pounds per acre foot before an attempt was made to analyze the data. Sixty-two field samples of both surface and subsoil were taken of the area affected two years after the plant had discontinued operation. The magnesium content was calculated on the basis of oxide, although it is recognized that little of it remains in that form after it reaches the soil. When the dust first leaves the stacks it is largely of an impalpable, amorphous nature and, with the exception of small amounts of unoxidized carbon and of uncalcined magnesium carbonate carried out with it, is composed almost entirely of magnesium in the oxide form. After it comes in contact with the soil and is exposed to the carbon dioxide of the air and to moisture it is soon converted into a comparatively stable

basic magnesium carbonate $[(4 \text{ MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 5 \text{ H}_2\text{O}) \text{ and } (3 \text{ MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3 \text{ H}_2\text{O})]$. The magnesium carbonate although not readily soluble in water acts quite differently in a soil solution containing carbon dioxide where the more soluble bicarbonate is readily formed $(\text{MgCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Mg H}_2(\text{CO}_3)_2)$. This reaction, in part, no doubt is also responsible for the fact that the toxic effect of the magnesium was most pronounced on soil high in organic matter or in soil where there was an opportunity for large amounts of carbon dioxide to be evolved.

It was found that although quite variable in its composition the normal surface soil contained about 4000 pounds of magnesium, calculated as oxide, per acre foot, while none of the samples, with possibly one exception, taken at a distance of one and a half miles from the plant and to leeward of it, contained 5000 pounds per acre foot. This amount increased toward the source of the dust, and as high as 56,000 pounds of magnesium oxide per acre foot were found within 100 feet of the plant. The subsoils of all samples were comparatively uniform in magnesium content irrespective of proximity to the plant. The average of all subsoil analyses shows about 5000 pounds of magnesium oxide per acre foot, or an amount slightly higher than for normal surface soil. It is not surprising to find a higher magnesium content in the normal subsoil because it is natural for all soluble substances in the soil to be carried downward. A sample of residual soil taken from within three feet above the magnesite rock at the mine supported splendid vegetation, and showed no higher magnesium content than is found in average productive soils. The fact, however, that the difference in composition between surface and subsoil is so slight, was of value to show that the magnesium deposit on the surface of these soils did not originate with the subsoil as a result of a "rise of alkali" as was somewhat generally contended by those who were not willing to acknowledge that the injury originated with the calcining plant.

To determine without question whether magnesium was either directly or indirectly responsible for the crop injury, soils from the fields surrounding the magnesite plant were collected and transferred to the greenhouse in an attempt to grow plants under controlled conditions. The samples of soil were taken from several locations at a distance of (1) 40 rods north, (2) 160 rods south, and 640 rods south of the calcining plant. These samples were then thoroughly mixed and two flowering pots were filled with each sample, so that each pot contained about 1000 grams of air dry soil. In each case one of these pots was left untreated,

and to the other, five grams of chemically pure magnesium carbonate ($MgCO_3$) were added and thoroughly mixed with it. Oats were planted and at the end of ten weeks the results represented in figure 1 were obtained.

The oats on the untreated soil taken at a distance of 40 rods from the plant all sprouted, but showed much the same brownish-yellow and generally sickly and stunted characteristics that were noted in the field.

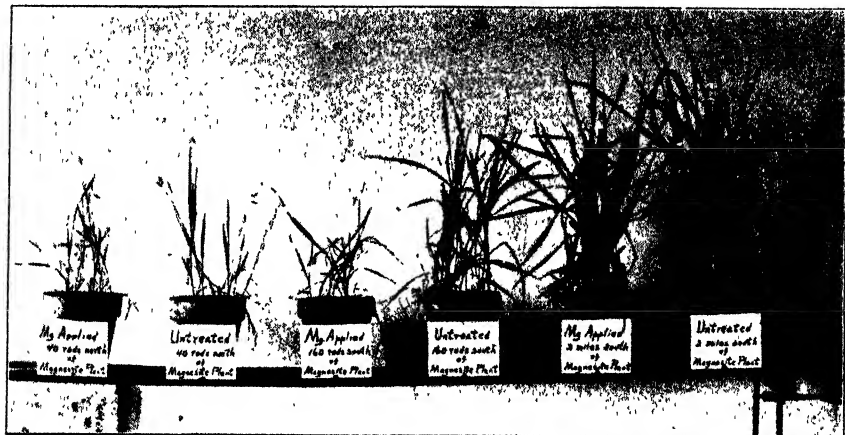


FIG. 1. The effect on plant development of magnesia dust deposited on agricultural land as a result of emanations from the stacks of a magnesite calciner. Soils at 40 rods from the calciner were injured so decidedly that crops failed without any further application of magnesium carbonate. Soils from a distance of two miles were not affected and could even withstand an application of five grams of magnesium carbonate per 1000 grams of soil in addition to the deposit in the field without any pronounced sign of injury. On soils at a distance of 160 rods the injury, although noticeable, had not reached a maximum and the addition of magnesium carbonate in the pot aggravated the effect very greatly.

There was little difference between results from the untreated and the treated soil taken at this distance from the source of the dust, both were failures and the addition of more magnesium carbonate could cause no further injury. On the untreated soil from a distance of 160 rods from the source of the dust, the oats, although still discolored, sickly and stunted, were in much better condition than those on the treated soil which showed that the injurious effect here had not yet reached a maximum.

The treated soil taken at a distance of 160 rods from the source of the dust produced a crop failure and in this respect was comparable to th

untreated soil taken at a distance of 40 rods as previously discussed. Soil from a distance of two miles produced good oats under both conditions, although those on the untreated soil were slightly better than on the treated. This shows conclusively that magnesium, when present in soils beyond certain amounts, produced injurious effects on this cereal, and that the normal soil in this valley in localities where it is outside the zone of influence from the calcining plant does not carry enough magnesium or alkali salts to cause injury to crops.

All of the land in this valley is being intensively tilled, and since the calciner discontinued operations, the farmer, in his efforts to bring the dust-injured soils back into producing condition, has, through plowing, caused the magnesite deposit to become thoroughly distributed through a comparatively large soil volume. This has caused much of the crust to disappear and has made for a less concentrated soil solution at the immediate surface of the ground with the result that there is no longer such pronounced physical and chemical injury to the crops, and the injured area is gradually decreasing in size. Just how long it will take before the entire area is reclaimed under conditions where future deposition of dust is prevented is a matter of time and climate conditions, as they influence soil moisture during the growing season, but it is quite evident that the present injurious condition is not of a permanent nature.

WASHINGTON AGRICULTURAL EXPERIMENT STATION.

A CHEMICAL AND PATHOLOGICAL STUDY OF DECAY OF THE XYLEM OF THE APPLE CAUSED BY POLYSTICTUS VERSICOLOR FR.

R. G. SMITH¹

This paper includes two proximate chemical analyses, the first of normal apple wood (*Pyrus malus* L.), the second of the same wood but altered in composition as a result of fungus attack (*Polystictus versicolor* Fr.) and in addition the proximate composition of equal volumes of the different woods with a proximate composition of the difference in weight of the two volumes.

LITERATURE

The author found a paucity of literature on the subject of complete wood analysis, less on the subject of wood analysis altered by fungus activity. Recent published articles of a physiological nature including chemical analyses are Tottingham (10) et al. on the composition of apple spurs and adjacent wood with special reference to the hemicellulose fraction, Butler (1) et al. on the proximate composition of different aged branches, trunk and roots of the apple tree at successive stages from spring dormancy to leaf fall. Hooker (6) made analyses of apple spurs including determinations of the true starch, at successive dates throughout the year. Articles dealing with the chemical aspect of wood analysis are confined to the special fractions, with the exception of the published papers of Dore (2-5). He has collected scattered methods, revised and improved analytical processes. Schorger (9) published an article defining the fractions of wood analysis.

PREPARATION OF MATERIAL

The xylem of an apple tree branch five years old partly altered as a result of fungus attack (*Polystictus versicolor* Fr.) was used for purpose of analysis. Identification was confirmed by Prof. W. T. Horne of the Dept. of Plant Pathology, University of California. The fungus altered wood was carefully removed with a knife and ground in a drug mill so that the powdered mass of wood passed through a sieve having

¹ The above work was carried on in the Div. of Plant Nutrition, University of California, under the direction of Prof. W. H. Dore.

The author wishes to express his appreciation for the suggestions and assistance given him.

50 meshes to the linear inch. The unaltered wood was obtained seven inches below the altered area in the direction of the trunk by repeated cross-sectional cuts (made with a cross-cut saw having 13 teeth to the inch) until the quantity of sawdust amounted to about 100 grms. The sawdust was ground and sieved the same as the altered.

ANALYTICAL METHODS

Moisture was determined by drying 2 gm. samples to constant weight at 100° C. Benzene extract was determined by extracting 2 gm. samples of the dried material in a Soxhlet apparatus for continuous extraction for 6 hrs. with benzene. The solvent was then evaporated and the residual extract dried for 1 hour at 100° C. and weighed.

Alcohol extract.—The residue from the benzene extraction was treated the same as above except 95 per cent alcohol was used as a solvent. The alcohol was evaporated off and the residue dried and weighed.

The alcohol soluble.—Sugars were determined by extracting two grms. samples in a Soxhlet apparatus for six hours with 80 c.c. of 95 per cent alcohol. The extract was evaporated to 10 c.c. taken up with boiling water, cooled, cleared with basic lead acetate delead with 10 per cent sodium carbonate filter washed, acidified with acetic acid made to volume and reducing sugars determined by Munson-Walker method (8). Reducing sugars as dextrose subtracted from alcohol extractive gives the non-sugars in the alcohol extract.

Starch.—This was determined by the taka-diatose method on the residue from benzene and alcohol extraction after gelatinising with 100 c.c. boiling water. The resulting maltose and dextrans were hydrolysed into dextrose and the amount determined by Munson and Walker's (8) method and calculated as starch.

Hemicellulose.—The residue from the starch determination was made up to volume of 100 c.c. one per cent hydrochloric acid and hydrolysed over a steam bath for three hours, filtered. The filtrate was boiled, neutralized with solid lead carbonate, filtered and washed, made to volume, and acidified with acetic acid. Reducing sugars determined by Munson-Walker (8) results converted to hexosan formula. Pentosan in the hemicellulose fraction were determined by taking aliquot proportions of above volume and distilling with 12 per cent hydrochloric acid (Krober method) (7) and calculating the yield of phloroglucid to pentosan sugar by Krober table (7). The pentosan weight was subtracted from the total hexosan and remainder expressed as hexosan. Cellulose was

determined by successive chlorinations after extracting with benzene and alcohol according to the method of Dore (3).

The residue from cellulose determination was distilled with 12 per cent hydrochloric acid (Krober method) (7) and the yield of phloroglucid calculated to pentosan (Krober table) (7). The pentosan weight was subtracted from the total cellulose and the remainder expressed as pentosan-free cellulose. Lignin was determined after extraction with benzene and alcohol according to Dore (3).

SPECIFIC GRAVITY DETERMINATION

The specific gravity of the unaltered and the altered wood was determined accurately by aid of the analytical balance. Cubic pieces of wood were taken from the altered area, and similar pieces of unaltered wood from seven inches below the altered area and directly opposite the altered area. All were dried to constant weight at 100° C., weighed, covered with paraffin by means of a camels hair brush and reweighed, then weighed held under water in a 50 c.c. breaker, on the pan of the analytical balance, by a slender steel needle. The weight of the paraffin covering cubes determined also its sp. gr. and the volume of water displaced by it subtracted from the volume displaced by combined volume of the paraffin covered wood. From this data the sp. gr. of the wood cube was determined.

FRACTIONS OF ANALYSIS DEFINED

In a complex organic substance of the nature of wood it is impossible to isolate completely the individual complexes of its formation; in our present state of knowledge the complexes are broken up into fractions which form the units of analysis. The following are the fractions used in this analysis and their content. Benzene alcohol extractive fractions are composed of fats, dyes, proteins, ethereal oil, resins and soluble reducing sugars, starch fraction, of starch. Hemicellulose fraction in the apple is regarded by Tottingham et al. (10) to be composed of hexosan and pentosan sugars identified by them as glucose, xylose and galactose. The above are considered by Schorger (9) to be the secondary constituents of wood, the main constituent being the lignocellulose complex, which is broken into the cellulose and lignin fractions. The cellulose fraction is defined by Dore (3) as a product prepared by processes of sufficient intensity to remove all extractives (resins, dyes, etc.), incrusting substances (lignin) and hemicelluloses (condensed carbohydrates of pentose, manose, glucose, and galactos basis), and limited in

their action to these bodies. It may contain A-B-and Y cellulose (mercerisation test) also furfural yielding complexes. Schorger's definition of the lignin fraction is "lignins are characterized as being carbohydrate derivatives containing methyl methoxyl, formyl and acetyl groups and consequently have a higher carbon content than cellulose or the hemicelluloses."

RESULTS OF ANALYSES

All results of the proximate analysis of altered and unaltered apple wood are given in the following table, in addition the proximate composition of equal volumes of the different woods with a proximate composition of the difference in weight of the volumes.

TABLE 1—*Result of analysis of healthy and decayed apple wood.*

Explanation of lettered columns given below							
	A	B	AA	BB	C	D	
Benzene Ext.	26	.55	1638	2420	+	0782	+ .32
Alcohol " { Alc. Sol.							
{ Sugars	1 36	1 34	8568	.5896	—	.2672	—31
{ Non-sugars	2 94	65	1 8522	2860	—1	5662	—84
Starch	3.00	3 51	1 8900	1 5444	—	.3456	—18
Hemicellulose { hexosans	4 54	3 08	2 8602	1 3552	—1	5050	—52
{ pentosans	1 59	3 88	2 8917	1.7072	—1	1845	—40
Cellulose { pentosan-free	40 96	38 19	25 8048	16 8036	—9	0012	—34
{ pentosan-in	14 05	8 24	8 8515	3 6256	—5	2259	—59
Lignin	25 09	35.96	15 8037	15 8224	+	.0157	+0.09
Undetermined	3.21	4 60	2 0223	2 0240	+	0017	+0 08
	100	100	63 Grms.	44 Grms	—19 Grms.	Per cent	

Results of analysis given in columns A and B: A being figures for unaltered wood and B those for altered wood expressed in percentage on moisture free basis. These results show a decrease in all constituents except benzene extract, lignin and undetermined. Lignin shows a marked increase and since no new lignin can be assumed to have formed it would appear probable that the increase is due to concentration by removal of other constituents. This data in itself does not show that lignin remains unattacked but it does show that it is at least much less attacked than other constituents. Further light, however, is thrown upon this matter by calculation based upon the specific gravities of the two samples. Unaltered wood has an apparent sp. gr. (i. e., an average sp. gr. including air spaces) of .63, altered wood .44. Since the volume

of the wood is presumably not altered by the fungus attack we may assume that the material which is finally contained in 44 grms. is the residue remaining from 63 grms. of original material.

Accordingly the analyses have been recalculated to a comparable basis; that in column AA representing analysis A recalculated to a basis of 63 grms., that in column BB representing analysis B calculated to a basis of 44 grms.

A comparison of these figures shows the relative amounts of each constituent before and after fungus attack. The differences are given in column C and the percentage differences in column D.

The change in the amount of lignin is negligible and within the experimental error of the analysis. The results accordingly tend to indicate that lignin is unchanged. The differences in the undetermined constituents are likewise negligible. The increase in benzene extract may possibly be due to the accumulation of resinous by-products incidental to the fungus activity. All other constituents appear to be definitely attacked.

LITERATURE CITED

- (1) BUTLER, O. R., T. O. SMITH, AND B. E. CURRY. Physiology of the apple. Distribution of food materials in the tree at different periods of vegetation. New Hampshire Tech. Bull. 13. 21 p., 8 fig. 1917.
- (2) DORE, W. H. The proximate analysis of wood. Jour. Indust. and Eng. Chem. **11**: 556-563. 1919. References, p. 563
- (3) ———. The determination of cellulose in woods. Jour. Indust. and Eng. Chem. **12**: 264-269. 1920
- (4) ———. The distribution of certain chemical constants of wood over its proximate constituents. Jour. Indust. and Eng. Chem. **12**: 472-476. 1920.
- (5) ———. The proximate analysis of hardwoods. Studies of *Quercus agrifolia*. Jour. Indust. and Eng. Chem. **12**: 984-987. 1920.
- (6) HOOKER, JR., H. D. Seasonal changes in the chemical composition of apple spurs. Missouri Agric. Exp. Sta. Res. Bull. 40. 51 p., 28 fig. 1920. Literature cited, p. 44.
- (7) KROBER, E. Untersuchungen über die Pentosanbestimmungen mittelst der Salzsäure-Phloroglucinmethode nebst einigen Anwendungen. Jour. Landw. **48**: 357-384. 1900.
- (8) MUNSON, L. S., AND P. H. WALKER. The unification of reducing sugar methods. Jour. Amer. Chem. Soc. **28**: 663-686. 1906.
- (9) SCHORGER, A. W. The chemistry of wood I.—Methods and results of analysis of some American species. Jour. Indust. and Eng. Chem. **9**: 556-561. Figs. 1-2. 1917.
- (10) TOTTINGHAM, W. E., R. H. ROBERTS, AND S. LEPKOVSKY. Hemicellulose of apple wood. Jour. Biol. Chem. **45**: 407-414. Fig. 1. 1921.

**ABSTRACTS OF PAPERS PRESENTED AT THE SEVENTH
ANNUAL MEETING OF THE PACIFIC DIVISION OF THE
AMERICAN PHYTOPATHOLOGICAL SOCIETY, LOS AN-
GELES, CALIFORNIA, SEPTEMBER 18 TO 21, 1923.**

Mosaic and other systemic disorders of raspberries in the Pacific Northwest. S. M. ZELLER.
Effect of rouging on spread of curly top in beets. F. C. TITUS.
Physiological specialization in Fomes Pinicola Fr. HENRY SCHMITZ.
American foreign plant quarantines. R. KENT BEATTIE.

SYMPOSIUM

Ecological factors influencing the distribution and severity of insect pests and plant diseases. Discussion lead by E. T. BARTHOLOMEW, H. J. WEBBER, H. S. FAWCETT, and H. H. P. SEVERIN.

This was a joint meeting with the Pacific Slope Branch of the American Association of Economic Entomologists, The Pacific Division of the Physiological Section of the Botanical Society of America, and the Ecological Society of America.

Decay of Douglas fir due to Poria incrassata. S. M. ZELLER.

Poria incrassata has been found to do rapid and extreme damage to Douglas fir structural timber and flooring when there is any contact with soil as a source of moisture. The spores germinate readily on damp soil or coniferous wood and rhizomorphs from 10-18 mm. diam. are formed leading to wood further from moisture supplies. The decay is brown and fragile.

Mosaic disease of loganberry. S. M. ZELLER.

Mosaic of loganberry is very destructive and widespread. Its present known range is from Sonoma County, California, to Snohomish County, Washington. In Oregon many 1 to 60 acre tracts have been grubbed out because of this disease. Nearly all younger plantings have from 3 to 95 per cent of the plants affected. Plants gradually decline and die out in 3 to 4 years after first symptoms appear.

Influence of time and temperature on the rate of growth of certain fungi. H. S. FAWCETT.

An experiment was performed in which the mycelia of two fungi (*Pythiacystis citrophthora* and *Diplodia natalensis* both citrus fruit rotting fungi) were allowed to advance continuously in large long glass tubes for periods of four and six months in uniform medium with only the slightly fluctuating temperatures of a dark basement room. After a short initial adjustment, both fungi grew during the long periods of the experiments at average rates fluctuating along with the fluctuating temperatures. Neither of these fungi appeared to be affected by the time element in their ability to respond to a given temperature. For example *Diplodia natalensis* is an average temperature of 15.1° C. during the 7th week advanced 23 mm. This same average temperature was again recorded in the 19th and 21st weeks in each of which the fungus advanced just 24 mm. The increment of growth dropped to 18 mm. on the 8th week at 14.1° C. and the same drop took place on the 20th week at 14.4° C. With *Pythiacystis citrophthora* an average temperature of 15.5° C. occurring on the 4th and again on the 11th week was accompanied by a growth of 27 mm. in each case. There appeared therefore to be no evidence of "staling" or slowing down with the age of the culture under the

conditions of the experiment. The range of temperatures experienced during the 6 months were from 12.8° to 21.1° C. Other previous experiments with the same organisms showed that for shorter periods of from 3 to 6 days and especially for higher temperatures the time element had an important influence on rate of growth.

Alternaria rot of lemons. E. T. BARTHOLOMEW.

Losses due to *Alternaria* rot are encountered in all of the lemon-growing districts of California. The decay almost invariably begins at the button (calyx cup plus receptacle) end of the lemon, the fungus gaining entrance through or under the button. Experiments have shown that there is a certain amount of button infection at about the time the petals are withering. Whether the mycelium produced in the tissues at this time remains in a dormant or semi-dormant condition while the fruit is maturing and then develops and produces the decay or whether the decay is more directly due to later infection by spores which have lodged in the crevices of the button or between the button and the lemon has not been definitely determined. Under ordinary conditions the lemon fruit itself never becomes infected until it is mature and even then not until certain unknown physiological changes occur which permit the fungus to invade the tissues. The invasion of the lemon tissue under the button usually takes place while the lemons are in storage or transit but it may occur on the tree if the lemons are allowed to remain unpicked until over-ripe. No medium has yet been found which will sterilize the button tissues without injury to the fruit. Spraying experiments are being conducted in the groves but without the hope of much success because of the 'almost continuous blossoming and setting of new fruits in most of the lemon growing districts.

The study of resistance to crown-gall in Prunus. C. O. SMITH.

About forty different species and numerous varieties of *Prunus* have been tested for crown gall resistance, using artificial inoculations as a means of infection.

A great difference in susceptibility has been found. In some diversified species as *P. domestica*, susceptible and resistant varieties have been found. In other species the seedlings and varieties tested seem to indicate that the species itself show strong resistance. Certain of the evergreen species (*Laurocerasus*) have shown total resistance. The species that apparently have strong resistance are *P. pumila*, *P. Besseyi*, *P. Mume*, *P. umbellata*, *P. alleghaniensis*, *P. scrotina*, *P. caroliniana*, *P. ilicifolia*, *P. tangutica* and some varieties of *P. domestica* and *P. insitula*.

The adaptability, under California conditions, of the resistant species, as stocks for the stone fruits is being tested. It is too soon to give conclusive results, but two species, *Prunus Mume* and *Prunus Besseyi* appear promising.

The resistant hosts of *Prunus* in many cases show a characteristic development of the hypertrophies. These are not typical subspherical galls, but are small in size, often cylindrical, mere point-like growths on the margins of the healing tissue. Many of them do not continue to develop and after a time disappear.

Effect of environmental conditions on western yellow blight of tomatoes. MICHAEL SHAPOVALOV.

The geographical distribution and the seasonal prevalence of western Yellow Blight of tomatoes depend primarily on climatic conditions. The disease tends to assume alarming proportions in localities and seasons characterized by a relatively high temperature, low humidity and high evaporation and is of little or no significance where

and when the humidity is high and the temperature and the evaporation are low. The rôle of climatic conditions in the development of Western Blight of tomatoes may be twofold: (1) direct upon the host predisposing the latter to the subsequent infection with parasitic or saprophytic organisms and (2) producing a set of conditions favoring aggressive activities of such organisms. There are clear indications as to the important effect of environments in bringing about the diseased conditions of the host aside from the interference of parasites. A progressive root decay has been invariably observed in connection with Western Tomato Blight. Several fungi, principally *Fusarium* spp. and *Rhizoctonia solani*, have been isolated from these decaying portions of the roots, but their exact rôle in the development of the complex symptoms of Western Blight has not been definitely determined. It is probable that a physiological collapse of small rootlets precede the fungus infection.

The behavior of certain varieties of tomato to the wilt disease (Fusarium) in California.

M. SHAPOVALOV AND J. W. LESLEY.

The possibility of controlling tomato wilt by means of resistant varieties has been tested at three places in Southern California during 1923. Artificial inoculations with pure cultures of *Fusarium lycopersici* as well as naturally infected soils were used to test the behavior of different varieties. Consistent results were obtained. Stone and San Jose Canner proved to be highly susceptible. With the former variety as a control, Globe, Columbia and some selections made in California and tested for the first time showed a fair degree of resistance. Norton, Norduke, Marvel, Louisiana Red, Louisiana Pink, Illinois New Century and a few unnamed selections appeared to be very resistant. Several of these gave correspondingly good yields. Perhaps Norton was the most promising and is probably much superior to Stone for planting on soils infected with wilt *Fusarium* in California.

* *A disease of tomatoes caused by Phytophthora mexicana* sp. nov. J. W. HOTSON AND LENA HARTGE.

This organism was isolated from tomatoes shipped into Seattle, Wash., from Mexico in the early summer of 1917. Cultural studies on artificial media, on the tomato plant and on the tomato fruit have shown it to be a species hitherto undescribed. This constitutes the fifth disease that has been reported on tomatoes in the United States and doubtless would become a serious pest if it once became established. The conidia ($16-33 \times 16-77 \mu$) are produced abundantly and vary greatly in size and form. The oospores are large, the greater number of them measuring 37μ in diameter. Only a few of these were observed germinating in Van Tieghem cells.

Recent advances in dusting methods RALPH E. SMITH.

Considerable difficulty has been experienced in the commercial preparation and handling of nicotine dust on account of the volatile nature of nicotine. Nicotine dust is also very expensive in proportion to the content of essential ingredients. It also requires the preparation and handling by dealers of a variety of strengths and combinations in order to meet the various requirements. The idea of the self-mixing duster is to have a dusting machine with which the original materials, like nicotine, lime, lead arsenate, sulphur or dry Bordeaux mixture, may be placed in the hopper in any desired proportion and the mixing accomplished there in the same operation as that of dusting. Any dry, powdered material may be used, also a liquid like nicotine sulphate solution

when mixed with any dry carrier which will absorb the desired amount of liquid and still remain dusty. Hydrated lime is the carrier commonly employed for making a plain nicotine dust. The mixing action of the self-duster is accomplished by putting an agitator into the hopper and passing the dust *through* the fan.

Immunity to mildew (Bremia lactucae Reg.) and its inheritance in lettuce. IVAN C. JAGGER.

A large number of varieties of lettuce have been tested and eight varieties found which seem entirely immune to mildew in both California and Florida. These varieties all appear to be of European origin and in general unsuited to American conditions. They have been hybridized with the popular variety Los Angeles Market or New York, which is sold on the markets as Iceberg lettuce. This variety is very susceptible to mildew. All first generation plants have been immune to mildew, and the few thousand second generation plants so far grown have given ratios which approximate three immune plants to one susceptible plant. Immunity seems to be inherited as a simple Mendelian dominant character. It is expected that hybridization and selection will give immune strains of the New York and other popular varieties of lettuce.

Bacterial slime disease of lettuce. RALPH E. SMITH AND ELIZABETH H. SMITH.

The growing of out-of-door lettuce for eastern and local shipment has increased very greatly in recent years. By the choice of different localities for different seasons it has been found possible to produce high quality lettuce practically throughout the entire year. The crop is grown in Imperial Valley during the winter, in various interior and coastward valleys in spring and early summer, and in certain very cool localities close to the coast during the summer and fall. In all these localities trouble is being experienced with a disease characterized mainly by a tip and edge burn of the leaves, running down into a slimy rot of the head. This causes serious losses in the field and in shipment and at times a demoralization of the industry. The disease usually first appears when the heads are just beginning to form and reaches its maximum development at the maturity of the crop. The occurrence of warm and humid weather appears to produce favorable conditions for infection. The universally grown "Los Angeles" variety is most susceptible. "Big Boston" and "Ice Berg" are less so. The trouble is of bacterial nature but has not yet been proven to be due to a single organism. It is similar to some of the diseases described by Brown.

Progress report on curly-top of the sugar beet. EUBANKS CARNSNER AND C. F. STAHL.

The project of developing a strain of beets resistant to curly-top has received the most emphasis from the writers during the past several years. Beets apparently resistant have been selected from seriously affected commercial and experimental fields. Seed has been grown from these plants with precautions against cross pollination. The progeny has been tested by plantings at Riverside, California, where natural infestations of the beet leafhopper regularly occur and also by inoculating each individual plant by means of viriferous leafhoppers. In the fall of 1921, 2611 and in the summers of 1922 and 1923, respectively, 2269 and 4403 plants were thus inoculated. These numbers include the controls of commercial seed. Marked resistance has been noted in some strains. During the current season a considerable number of individual plants which were diseased in May or early June developed roots weighing 2 to 5 pounds. Plants from ordinary commercial seed usually die or produce only worthless roots if

infected so early. A serious handicap has been encountered in the tendency of some of the most promising strains to produce seed stalks the first season. This objectionable character is thought to result from climatic influences. If so, it can be overcome.

Results with *Chenopodium murale* are interesting in connection with the question of resistance to curly-top. All of our earlier inoculations of this species and most of those later have given negative results. In some cases, however, positive evidence that the plants contracted the disease has been obtained. A peculiar development in some of the positive cases indicates that by passage through this resistant plant the virus may be attenuated or modified.

A recent development of significance in the curly-top problem has been the production of the disease by artificial inoculation. This has been done by H. P. Severin. Subsequently it was accomplished by one of the writers. A few positive cases were obtained from a considerable number of trials by using expressed juice of diseased beets and also small pieces of diseased beet tissue. In view of this development there is more justification than formerly existed for classifying curly-top as a mosaic disease.

Curly leaf transmission experiments. HENRY H. P. SEVERIN.

Juice pressed from the leaves and roots of curly leaf beets when inoculated into the crown of healthy beets caused typical curly leaf symptoms in nine of one hundred beets. The period from the date of inoculation until the earliest symptom of curly leaf developed varied from 12 to 39 days. Non-infective beet leafhoppers, when allowed to feed on the inoculated beets after curly leaf developed, transmitted the disease to healthy beets, the earliest symptom appearing in from 2 to 13 days.

The shortest time required for the infective principle of curly leaf to travel through a beet petiole seven inches long was one-half hour at a mean temperature of 103.5° F. Infective beet leafhoppers were placed on a beet seedling feeding on the inner or youngest leaf, and at the same time non-infective males placed on one of the outer or oldest leaves became infective at the end of two days, as was proved by transferring them to a healthy beet. Similar results were obtained from one outer leaf to the opposite outer leaf and from one cotyledon to the outer leaf.

Infective beet leafhoppers retained their infectivity during all of the nymphal stages, after each molt, and during the entire adult life, as was demonstrated by supplying each insect with a healthy beet daily.

Mosaic and leaf roll of potatoes in Idaho. CHAS. W. HUNGERFORD AND J. M. RAEDER.

Mosaic and leaf roll are among the most important and destructive potato diseases in Idaho. There are at least three distinct types of mosaic in the state, each apparently distinct. The green and pink rose aphid is plentiful in the potato growing districts and experiments have shown that it may transmit the russet dwarf type of mosaic under Idaho conditions. Environmental conditions may influence the appearance of mosaic in any given seed lot. This may be due to masking of symptoms or to infection from local sources. The russet dwarf type of mosaic may appear as slight mottling late in the season soon after infection has taken place and progeny from such plants may develop very severe advanced stages of the disease. Primary symptoms of leaf roll may appear as slight rolling of the upper leaves late in the season on otherwise vigorous plants. Progeny from such plants may develop leaf roll in very advanced stages.

A root-rot and wilt of udo. J. L. WEIMER.

Two diseases of udo (*Aralia cordata* Thunb.) have been investigated. The roots of this plant are sometimes completely destroyed by a soft, wet rot. The infected tissues are permeated with hyphae, which soon form numerous black sclerotia within and on the surface of the decayed roots. No fruiting stage of the causal fungus has been seen but the mycelium and sclerotia appear to be those of *Sclerotinia libertiana* Fel. The fungus has been isolated and its parasitism proved. The disease has also been produced by inoculating udo plants with *Sclerotinia libertiana* from pure authentic cultures.

The udo is also subject to a wilt disease caused by *Verticillium albo-atrum* R. & B. This disease resembles the wilts produced in other plants by the fungus. The causal fungus has been isolated from diseased udo plants and the disease produced by inoculations with it from pure cultures. The details of these investigations will be published in the Journal of Agricultural Research.

Investigative work on white pine blister rust in the Pacific Northwest for 1922. J. S. BOYCE.

The disease was probably introduced on the Pacific Coast in 1910 on a shipment of eastern white pines from Ussy, France, which were planted at Vancouver, British Columbia. It is now widespread in the coast region of British Columbia and Washington and has also been found at several places in eastern British Columbia.

Assuming Vancouver as the principal point of origin and the date of introduction as 1910, in 12 years the rust has extended over a triangle of country roughly 300 miles or more on a side.

Dry growing seasons retard the spread of the rust and wet seasons greatly accelerate the spread. All the western species of *Ribes* and *Grossularia* so far found in association with diseased pines are susceptible to infection although in varying degree. Western white pine is subject to very severe injury and it seems more susceptible than eastern white pine.

A new disease of cultivated barley in California caused by Helminthosporium californicum, n. sp. W. W. MACKIE AND G. E. PAXTON.

An undescribed species of *Helminthosporium* has been observed to be generally distributed and abundant in California on cultivated barley. Its period of development begins much later than that of other *Helminthosporium* species previously described. It appears with the warm, dry weather and develops rapidly. The apical ends of the leaves are first attacked and finally a "rusty blotch" is formed on the leaves. The lower leaves are first attacked and the disease progresses to the top of the plant. The grain is shriveled due to the premature death of the leaves. The spots are irregular, brown to bluish black, usually merging into diffused brownish discoloration of larger part of leaf. The spots are not netted (*H. triseti*), elongated (*H. gramineum*), or definitely bounded dead areas (*H. sativum*). The conidia of *H. californicum*, n. sp., are dark olivaceous when fully mature; fusiform, not curved; thick walled; $40-85\mu \times 20-26\mu$; average $58 \times 22\mu$; 3-9 septate. Germinate by single germ tube from any segment. It resembles *H. sativum* P. K. & B. except that it occurs later, is more severe, the diseased areas are not definite and have no distinct margins. The conidia are longer, wider, more dense, thicker walled and not curved. The rusty blotch which has been observed for four years in California has been determined to be a new species of *Helminthosporium* and has been named *H. californicum*. It has been increasing in severity in the Sacramento and San Joaquin Valleys. Studies carried on show marked varietal resistance to this disease.

Some diseases new to California. E. H. SMITH.

The following diseases are reported as occurring in California, with brief discussion:

Kale, Cabbage, and flowering stock	Fusarium yellows.
Raspberry blue stem	(<i>Verticillium</i> sp.)
Sweet pea root rot	(<i>Thielavia basicola</i> [B. & Br.] Zopf.).
Wine grape fruit rot	(<i>Botrytis cinerea</i> Pers.).
Alfalfa stem Nematode	(<i>Tylenchus dipsaci</i> Kuhn.).
Asparagus leaf and stem spot	(<i>Cercospora</i> sp.).
Almond scab	(<i>Cladosporium carpophilum</i> Thum.).
Sunflower and Onion crown rot	(<i>Sclerotinia</i> sp.).
Sugar beet	(<i>Rhizoctonia</i> rot).
Watermelon leaf mildew	(<i>Pironoplasmopara cubensis</i> [B. & C.]).

PHYTOPATHOLOGICAL NOTES

Red plum curl (caused by Exoascus mirabilis Atk.). A serious disease of red plums was collected in southern Illinois by Dr. H. W. Anderson in 1920 and, in 1922 and 1923, field men working in the Illinois State Natural History Survey reported it from seventeen counties in the southern and central parts of the state. Usually $\frac{1}{2}$ -5 per cent of the twigs on infected trees are killed. The causal fungus was identified as *Exoascus mirabilis* Atk. (Bull. Torrey Bot. Club **21**: 376. 1894) by Miss Anna E. Jenkins of the Federal Office of Pathological Collections. Its macroscopic characteristics agree closely with those of the very similar *Exoascus decipiens* Atk. as pictured by Swingle and Morris (Mont. Agr. Exp. Sta. Circ. 77: Fig. 6. 1918). Infected leaves are partially or wholly distorted. They are greatly thickened and mostly unexpanded, merging imperceptibly into irregularly spatulate and greatly hypertrophied twigs. Infected twigs are green at first, later drying and becoming gray to black. Infected tissue resembles that of plum pockets and becomes brittle when mature and dry. Red plum curl is not of great economic importance in Illinois because no large quantity of plums is grown for the market here.—PAUL A. YOUNG.

On the names Sclerotinia sclerotiorum (Lib.) Massee, and S. libertiana Fuckel. Both in the United States and Europe there is a large and increasing volume of literature on this common and fairly omnivorous parasite, with, however, a discrepancy in nomenclature which seems to require explanation.

American papers, almost without exception, refer to the fungus as *Sclerotinia libertiana* Fuckel, and in the latest of these ("Taxonomy of the *Sclerotinia* on *Helianthus annuus* L." by Mrs. Seymour Jones, in *Phytopathology* XIII, Nov. 1923, p. 496), the name *S. sclerotiorum*, under which the fungus is generally known in this country, is definitely relegated to a subordinate place as a synonym of *S. libertiana*.

Enquiry into the history of the species shows at once, however, that the reverse is the case.

The fungus was distributed in 1837 by Madame Libert in her *Pl. Crypt. Arduennae*, Fasc. IV, No. 326. The name *Peziza sclerotiorum* was given to it, and was accompanied by a Latin description, the whole constituting perfectly valid publication. Fuckel in his *Symbolae My-*

cologicae (1869-70) transferred the species to his genus *Sclerotinia*, and at the same time changed the name to "*S. Libertiana*", presumably merely because he disliked the combination *S. sclerotiorum*. Fuckel left no doubt as to his plant, for he cited as synonyms *Peziza sclerotiorum* Libert and another name of his own, *P. Sclerotii* Fuckel.

Now this name-change by Fuckel is definitely contrary to the rule embodied in both the American Code and the International Rules of Nomenclature, and now generally accepted, namely, that when a species is transferred from one genus to another the original specific name is retained, unless the resulting combination is already preoccupied. In the case of *S. sclerotiorum* there was no such previous use of the combination, because Fuckel himself proposed the genus. Consequently according to all the rules of nomenclature at present accepted there is no justification for the perpetuation of Fuckel's name.

As a matter of fact nearly all other European workers have adopted Madame Libert's specific name. Gillet in 1879 called it *Phialea sclerotiorum*, and Phillips in 1887 put it in *Hymenoscypha* (sub-genus *Sclerotinia*) *sclerotiorum*. Boudier however adopted Fuckel's name.

The actual combination *Sclerotinia sclerotiorum* was apparently first used by Massée in Vol. IV of his British Fungus Flora (1895) and has been retained in all English pathological literature since.—ELSIE M. WAKEFIELD, (KEW).

H. Morstatt. Einführung in die Pflanzenpathologie. Pp. 157. 1923.

The book comprises a complete, though short treatise, of the subject of plant pathology, embracing, however, not only the study of phytopathology proper, but also of entomology in so far as the latter is related to the study of plant diseases. The work naturally divides itself into four parts: (a) symptomology, (b) aetiology, prognosis and diagnosis, (c) the causes of plant diseases, and (4) disease control. Under symptomology, the writer treats general disease manifestations such as: wilting, discoloration, necrosis, structural malformations, and outlines the procedure to be followed in the description and investigation of plant diseases. The second chapter, which is by far the most interesting assembles concisely, yet thoroughly much recent information on the nature of plant diseases, the significance of predisposition and immunity, the inheritance of resistance, and the contributions made by studies in pathological anatomy and physiology. The chapter on causes is a synopsis of disease producing bacteria, fungi and animal parasites. Under inanimate causes are considered the effects of unfavorable weather

and soil conditions, smoke, gas and spray injuries. The chapter on disease control recommends such practices as are generally employed in plant pest control in America. The book furnishes a valuable compilation of recent developments and views upon which progress in the science of plant pathology is being made. It will be useful to all students of the subject for its complete and authentic treatment of the principles of plant pathology.—ERNST ARTSCHWAGER.

Personals. The Department of Agriculture of Bermuda has appointed its first permanent Plant Pathologist, in the person of Mr. Lawrence Ogilvie. Mr. Ogilvie is a graduate of Aberdeen University, Scotland. He has done graduate work in Botany and Entomology in the University of Cambridge. I desire to enlist for Mr. Ogilvie the assistance and co-operation of American Plant Pathologists. Reprints, bulletins and other publications bearing on plant diseases will be especially helpful for this young Pathologist in his first position.—H. H. WHETZEL.

Dr. F. Dickson of Cornell University is assuming a position as Professor in the Department of Botany, University of British Columbia, Vancouver, B. C., Canada.

Dr. Arthur S. Rhoads, Pathologist of the Missouri State Fruit Experiment Station, has accepted the position of Assistant Plant Pathologist of the Florida Agricultural Experiment Station.

The January number of Phytopathology was issued February 11, 1924.



JOHN ASBURY ELLIOTT

PHYTOPATHOLOGY

VOLUME XIV

MARCH, 1924

NUMBER 3

JOHN ASBURY ELLIOTT

T. F. M A N N S

WITH PLATE II

John Asbury Elliott was born in a sod house on the prairies of Western Kansas, December 1, 1887, near the little village of Ness City; he died January 18, 1923, at Washington, D. C., to which city he went directly after attending the A. A. A. S. meetings in Boston. His boyhood was spent largely on a farm near the place of his birth. I can understand every motive that prompted his love for the wild flower, the hop toad, the arrow top, the buffalo trail, the migrating bird, the creeks, the ponds and the prairies. He used to say to his mother, "I don't see why anyone can live anywhere but on the prairie, it is so beautiful." His interest for plants and birds never left him; his love for nature was so great that the glare of the Metropolis never tempted him. As "sidewalks tend to produce city mindedness" so likewise one born in the lap of nature is lead naturewards.

In the fall of 1909, he entered Fairmount College, of Wichita, Kansas, and received his Bachelor's Degree with the highest honors in 1913. As an undergraduate he majored in botany. The year following graduation he held a fellowship in botany at the University of Kansas, and received his Master's Degree in 1914. The next two years he was a Fellow in Plant Pathology at the University of Illinois, and was awarded the degree of Doctor of Philosophy in 1916. In all the institutions he attended he was recognized as a student of remarkable ability. Dr. Elliott began his career as Associate Plant Pathologist at the University of Delaware. In the summer of 1917, he was elected Professor of Plant Pathology in the College of Agriculture and Plant Pathologist of the Experiment Station of Arkansas, which position he held at the time of his illness.

Dr. Elliott was married to Miss Margaret Elizabeth Allen of Wichita, Kansas, on June 10, 1916. He is survived by his wife and two children.

Professor Dwight Isley, Associate Entomologist in the College of Agriculture, Arkansas, made the statement:—"As an investigator, Dr.

Elliott was characterized by a thorough appreciation of the fundamentals of his science, coupled with common sense. By this somewhat rare combination, he avoided both the narrowness and isolation so often associated with the technical specialist and the superficiality which sometimes characterizes the practical worker. His mind was broad enough to comprehend at the same time both the basic and applied aspects of the problem. One or two illustrations since coming to Arkansas will illustrate this:

"One of the first problems undertaken by Dr. Elliott was the prevention of losses which sweet potato growers suffer annually, due particularly to two diseases known as black rot and wilt. It was established that both these diseases were spread by infected seeds and slips. According to the practice then in vogue, anyone buying seed or slips had no protection from these diseases but was likely at any time to introduce them into his field. At Dr. Elliott's suggestion, the situation was met by a system of seed certification by the State Plant Board, of which Dr. Elliott as Plant Pathologist was a member.

"Sweet potato certification, for which Dr. Elliott was in large part responsible, is based not only on sound pathological sense, but also on a sense of human nature. It provides for an inspection of sweet potato fields which, if they pass inspection, may be certified for seed. The inspection is entirely voluntary and is made only at the request of the seed growers. Compulsory inspection would have failed. Purchasers may then, if they choose, buy seed or slips that are free from disease. This plan of seed certification has been eminently successful in protecting the sweet potato industry of Arkansas, and has been copied by the Plant Boards of most of the Southern states.

"Dr. Elliott's most important investigative achievement from the point of view of prevention of economic loss, was in relation to the control of the boll rots by delinting cotton seed. Boll rots of cotton cause the South an annual loss of perhaps 10 per cent of the cotton crop. In a state like Arkansas in which the cotton crop means 40 per cent of the state's wealth, such a loss is no mean item. Nearly all the boll rots are either directly due to or are instigated by a cotton disease known as angular leaf-spot. The relation of this organism to boll rots was first established by Dr. Elliott. The ability required to solve this phase of the problem is clearly shown by the fact that for many years southern pathologists had failed in its solution. Delinting cotton seed, and thus destroying the organism carried on the lint, was first tried as a means of control in the laboratory and then on plantations in various parts of

the state on a larger scale. While it may be several years before the value of planting of delinted seed will be generally recognized by the cotton growers of the state, the financial returns to the cotton belt, due to this discovery, will amount to millions of dollars annually."

In the short period of six years, Dr. Elliott published a score or more of papers, including the following:

- A study of the histological variations of *Quercus muhlenbergii*. Univ. of Kansas Sci. Bull. **9**: 43-54. Pl. 8-15. 1914. Bibliography, p. 54.
- An *Alternaria* on *Sonchus*. Bot. Gaz. **62**: 414-416. 1916.
- The sweet potato "Soil Rot" or "Pox," a slime mold disease. Delaware Agric. Exp. Sta. Bull. 114. 25 p., 5 pl., 13 fig. 1916.
- Taxonomic characters of the genera *Alternaria* and *Macrosporium*. Amer. Jour. Bot. **4**: 439-476. Pl. 19-20, 6 fig. 1917. Literature cited, p. 474-475.
- The conduction of potassium cyanide in plants. Phytopath. **7**: 443-448. 2 fig. 1917.
- Arkansas peach diseases. Arkansas Agric. Exp. Sta. Bull. 149. 9 p., 5 pl. 1918.
- Storage rots of sweet potatoes. Arkansas Agric. Exp. Sta. Bull. 144. 15 p., 4 pl. 1918.
- A smut on *Iresine*. Mycologia **2**: 87-88. 4 fig. 1919.
- A mosaic of sweet and red clovers. Phytopath. **11**: 146-148. 1921.
- Arkansas cotton diseases. Arkansas Agric. Exp. Sta. Bull. 173. 26 p., 5 pl. 1921. Literature cited, p. 15.
- A new *Ascochyta* disease of cotton. Arkansas Agric. Exp. Sta. Bull. 178. 18 p., 4 pl., 1 fig. 1922. Literature cited, p. 18.
- Some characters of the southern tuckahoe. Mycologia **14**: 222-224. Pl. 17-18. 1922. Literature cited, p. 227.
- The spread of tomato wilt by infected seed. Phytopath. **12**: 428-434. Pl. 28, 2 fig. 1922. Literature cited, p. 434. (Joint author with R. F. Crawford.)

His unpublished manuscript included several titles; two important ones of these are, "A Cytological Study of *Ceratostomella fimbriata* (E. & H.) Elliott." "The Breeding of Wilt Resistant Varieties of Tomatoes for Arkansas."

Dr. Elliott was a member of the American Association for Advancement of Science, American Botanical Society, American Phytopathological Society, American Society of College Professors; he was elected to the honorary society Sigma Xi.

OVERWINTERING OF TOBACCO WILDFIRE BACTERIA IN NEW ENGLAND

P. J. ANDERSON

One of the most baffling characteristics of the wildfire disease in the Connecticut Valley is its sudden and widespread recurrence every spring in the tobacco seed-beds. How do the bacteria from which the epiphytotic starts each year come into so many seed-beds? Where have they been during the six or eight months of winter, when everything is frozen up and there are no green leaves on which to live? Obviously the correct solution of this problem is of great importance to the pathologist who is seeking a better method of controlling wildfire. His first impulse is to say that the bacteria must be in the soil; but sterilization of the seed-bed soil is the rule with tobacco growers here and yet those who sterilize do not escape with much less infection than those who do not sterilize. In a previous publication (1:4)¹ Anderson and Chapman have presented sufficient reasons for believing that infected seed does not account for any large percentage of the trouble. Work on the overwintering problem was begun very soon after the disease appeared in Massachusetts, but although certain ways in which the organism might pass the winter were found, none of them seemed sufficient to account for a widespread simultaneous initial appearance of the disease such as we have experienced in the early spring for the last three years.

During the winter of 1922-23, the writer continued this investigation and believes that he has been able to add somewhat to our previous knowledge of the wintering problem. The experiments and his conclusions from them are presented in this paper.

EFFECT OF ALTERNATE FREEZING AND THAWING

In a previous publication (1:3) it has been shown that the bacteria are able to withstand considerable periods of freezing. But it is conceivable that alternate freezing and thawing might be more destructive. Neither was it proved in the previous experiments that they were still capable of producing infection after being frozen, when transferred to healthy plants. In order to determine these points, agar cultures were placed out doors in December and kept there during one of the most severe winters which New England has experienced in forty years.

¹ First number in parentheses refers to publication cited at close of this article; second number to page cited.

During the spring months they frequently thawed and were again frozen. At various times during the spring and summer of 1923 bouillon was poured into some of the tubes and in the majority of cases it clouded within a few days, indicating the multiplication of the bacteria. Typical lesions of wildfire were produced when tobacco plants were sprayed with these bouillon cultures. The last culture was tested and found to be still virulent after almost a year. The fact that the bouillon did not cloud in all cases indicates that a part of the bacteria were killed.

These results show that all the organisms are not killed nor rendered innocuous even during the most severe winter here. When, under certain conditions to be described below, they fail to survive the winter, it cannot be due merely to the unfavorable effect of freezing or of alternate freezing and thawing.

WINTERING IN THE CURING SHEDS

In May, 1923, diseased leaves were collected every week from the floor of a tobacco shed where they had been thrown when the tobacco was stripped during the winter. When these leaves were pulverized and dusted over wet growing tobacco plants the typical disease was developed at every test. Similar experiments conducted at different times by the writer (1:7) in Massachusetts and by Slagg and Chapman (1:7) and by Clinton and McCormick (2:417) in Connecticut invariably gave the same results. The ease and certainty with which virulent cultures have been taken from these cured leaves by every investigator proves that the bacteria must live over in great numbers and in virulent condition in the sheds. Such experimental data, strengthened by considerable observational evidence, incline the writer to believe that here is the principal source of the spring infection.

But after it has been demonstrated that the shed in which wildfire tobacco has been stored is full of potential contagion, the next step is to inquire how abundant are the opportunities for such infectious material to reach the seed beds or young plants in the field and thus start the spread of another year. Several ways in which this may be brought about have been mentioned in a previous publication (1:7). Additional observations have confirmed the suggestions made there and have uncovered other methods of accomplishing the transfer. In wildfire years it has been a common practice when the tobacco is stripped and put in the bundle to throw out the badly spotted leaves in order to avoid a cut in the price of the crop. The discarded leaves are either left on the floor of the shed or are carted out later. If left on the floor, they are

tramped over throughout the winter and spring and fragments of them carried on the shoes to all parts of the farm. Frequently wagons and tools are stored in the shed and on the wheels and tools, other fragments are carried out to the land. Even when the discarded leaves are carried away, broken parts are left on the shed floor and may be carried out in the same way. The carted-out leaves are usually thrown somewhere on the land. The chance of infection starting from these leaves thrown back on the land will be discussed presently. The minutest fragment of a leaf may be sufficient to start trouble in the beds. Such fragments may be blown by the wind from the loose sheds or from the loads of tobacco which are being carted away or from tools, etc. The same rake with which the discarded leaves are removed from the floor of the shed is often used in preparing the seed-bed. When one stops to consider the many possible ways in which the infected material from the shed may reach the new plants, one is not surprised at the abundant spring infection but wonders rather how any of the plants in the vicinity can escape. In several fields, the writer has observed field infection starting close to the tobacco shed, while the remainder of the field was clean. The inference from such cases is obvious. The tobacco shed undoubtedly furnishes the ideal winterquarters for *Bacterium tabacum*.

WINTERING IN LEAVES THROWN BACK ON THE LAND

It has just been stated that discarded spotted leaves are sometimes carted back onto the land. Such a case was investigated on a farm in South Amherst. After the owner stripped the tobacco in the late fall or early winter of 1922 he carted the refuse leaves out to land which he did not intend to use for tobacco. Here they remained all winter on the land—under the snow through a considerable part of the winter—but were not disintegrated by decay. On April 24, masses of them which were very badly weather-worn but on which the lesions were still visible were ground up and dusted on young plants. Wildfire lesions were apparent on these plants within ten days, thus demonstrating that the bacteria had survived under these conditions. Part of the material was placed back on the soil to be tested later. On the 31st day of May it was examined again and found to be pretty well rotted. Attempts to inoculate young plants with it were unsuccessful. Apparently the bacteria had died when the leaves rotted.

In the face of the positive evidence which we now have there could hardly be any doubt but that the bacteria survive the winter in such leaves which are not disintegrated. Being thrown out on the land, even

if it is not to be planted to tobacco, they could be blown easily to fields where tobacco is grown.

OVERWINTERING IN PLANTS LEFT STANDING IN THE FIELD

Occasionally badly diseased plants are not harvested but left standing in the field. Also, after the tobacco is harvested, suckers grow rapidly and if the fall is late may reach a height of two or three feet. In the wildfire years of 1921 and 1922 wildfire was extremely abundant on these suckers. In order to determine whether diseased plants like these which die and remain standing in the field through the winter might serve as a source of spring infection some badly diseased plants were left standing in a South Amherst field through the winter of 1922-23. On April 23 and on later dates up to May 25, some of the leaves from these plants were ground and dusted on to young plants. The results were positive in every test. Lesions developed on every inoculated plant. The leaves on these wintered plants were not disintegrated but remained dry and intact except that they were somewhat shredded and blown away by the wind. Under these conditions the organisms seem to be able to survive excellently. Such plants could very easily serve as centers of infection for the coming year.

WINTERING IN LEAVES BURIED IN THE SOIL

When tobacco leaves are buried, they disintegrate so rapidly that within a few weeks hardly a trace of them can be found. It was therefore found necessary to bury them between wire screens in order to be able to locate them when dug out again. In August, 1922, a quantity of very badly diseased leaves was buried in this way and left until May 7, 1923. When dug up, only small traces of leaves between the screens could be found but these traces and adhering soil were rubbed on wet punctured tobacco plants in the greenhouse. The same thing was repeated three times later up to June 13. None of the inoculated plants ever showed a trace of wildfire.

In a second experiment diseased leaves were chopped in a box of soil until the mixture was about 50 per cent leaves. This box of soil was then left outdoors all winter. Beginning on April 24, 1923, portions of this soil were rubbed on tobacco plants as in the preceding experiment but always with the same negative results. Tobacco seed was also planted in this soil on two different occasions. Only in one instance did any infection result and that one was late in the summer and there was good evidence that it came from a different source. Disregarding this

one case, all the other evidence indicates that the bacteria do not survive in these leaves which rot in the soil. Green leaves were also placed on top of the soil in September, 1922, with the intention of testing for the presence of bacteria in the spring of 1923 but they rotted so completely that no trace of them could be found in the spring.

WINTERING IN THE SOIL

We have presented abundant evidence (1:6) to show that the wildfire bacteria may exist for short periods in the soil and infect other plants from this source. But this does not mean necessarily that they are able to pass the winter in the soil. What little evidence we have on soil wintering is contradictory and not convincing. In the bulletin cited above we have presented the evidence on both sides and closed with the statement that the evidence is not convincing. Clinton and McCormick (2:376) correctly state that "we have very little convincing data along this line."

In Massachusetts Experiment Station Bulletin 213, p. 6, we have described an experiment in which the bacteria were kept in flasks of previously sterilized soil in pure culture from July, 1921, to March, 1922 and were still able to produce infection. In this experiment however the soil was not exposed to the weather but was kept in the laboratory and the soil was dry. Even in this experiment when the soil was kept too wet, they died before the expiration of the experiment.

In December, 1922, the above experiment was repeated but the flasks of soil kept outdoors during the winter. Some of this soil was placed on tobacco plants on April 23 and produced infection. The experiment was repeated on May 8, and on June 14. Infection resulted in every case, thus demonstrating that the bacteria can survive the winter when kept *in pure culture in previously sterilized soil*. But in nature they are not in pure culture. In order to more closely duplicate natural conditions, flasks of soil which had not been sterilized were inoculated and kept outdoors for the same length of time and under the same conditions as those previously mentioned. Inoculations were made at the same time as the above but no infection resulted in any case. The soil in these flasks was a little more moist (probably because of the drying effect of sterilization); otherwise the conditions were the same. This experiment leads one to suspect that the wildfire bacteria are killed by competition with other organisms.

In another experiment soil was collected from beneath the worst infected plants which could be found in the fall of 1922, kept over winter

outdoors and then rubbed on young plants in the spring. The inoculation was repeated a number of times but with consistent negative results. Seed was also planted in this soil but the plants never showed any infection.

In another experiment soil was taken from the base of the infected plants which were left standing in the field all winter in South Amherst. All attempts to inoculate with this soil resulted in failure.

In another experiment soil was taken from beneath the diseased leaves which had been thrown back in the field previously mentioned in South Amherst. No infection could be obtained from this soil.

The previously mentioned box of soil in which diseased leaves were chopped must have been teeming with bacteria but no infection in the spring resulted from rubbing this soil on wet punctured tobacco leaves.

Every attempt which the writer has made to get infection from unsterilized wintered soil has failed.

The fact that clean crops were grown on some fields during 1922 which had grown diseased crops in 1921 is in line with these data. The fact that in some fields wildfire has been observed in approximately the same location during successive years may be accounted for by sucker wintering or—in some cases at least—by proximity to tobacco sheds.

The evidence for soil wintering is so overwhelmingly negative that we are probably justified in concluding that in New England the wildfire bacteria do not winter in the soil or at most that this is a very minor source of spring infection.

WINTERING ON THE SASH AND SIDEBOARDS

Some evidence has been published previously (1:14) to show that the bacteria may remain alive on sash or on plank used for sideboards and thus become a source of infection in the spring. The evidence however is not conclusive. The following experiment was conducted during the winter of 1922-23 to determine whether the organism on dry wood such as the sideboards or sash may survive the winter and infect in the spring. In December, small blocks of pine wood were sterilized and then soaked in a pure culture of the bacteria. After a few hours, the blocks were removed from the cultures and kept in plugged test tubes outdoors all winter (an extremely severe winter). During April, May and June cultures were obtained from these blocks and the disease readily produced from these cultures. There are two ways in which the conditions in this experiment are different from those which might prevail on the farm. In the first place the bacteria were in pure culture, i. e., there were no other organisms on the wood. In the second place, the

blocks froze up before they were very dry and remained so until they thawed out in the spring. When however it is recalled that sash and plank may be stored under all gradations of moisture and that long desiccation (e. g., in leaves) does not kill the bacteria, it seems hardly likely that the conditions which were necessary for the experiment should influence the interpretation of the results.

All the evidence at hand from laboratory experimental data and from field observations too numerous to describe here indicates that sash and plank which have become contaminated by the growing of diseased beds or by being stored in or near sheds where diseased tobacco is stored may be regarded as sources of danger for the following crop.

WINTERING WITH THE SEED

In the South, the pathologists consider the seed as the principal carrier of bacteria from one season to the next. They therefore place especial emphasis on seed sterilization as a control measure. Reasons for believing that this is not an important source of spring infection in the Connecticut Valley are presented in a previous publication (1:4). In an effort to see whether a case of seed transmission could be found here, the seed plants in many fields were examined in the autumn of 1922. No infected pods were found except in one field in North Hadley. In this case the leaves of the plants were badly spotted and some lesions which were thought to be wildfire were on the pods. Such pods were gathered, dried and stored in a stoppered flask in the laboratory. In the spring they were threshed out and sprinkled over wet punctured leaves in the greenhouse but no infection resulted.

In a second experiment the pods of some plants in the greenhouse were punctured and inoculated from pure cultures during the autumn and abundant infection resulted. These pods were harvested and kept just as those previously mentioned. In the spring some of them were ground in a mortar and sprinkled on wet punctured leaves as above but with negative results. When however some of them were sowed, the resulting seedlings became infected while a plot of seedlings treated exactly like them but from disease-free seed, remained healthy. Here seems to be good evidence that if the bacteria are in the pods, they may live over and produce infection in the succeeding crop. There is no reason for believing that they would not live over in dry pods just as easily as in dry leaves. Pod infection has been seen so rarely in the Connecticut Valley tobacco section however and most growers are so careful not to save seed from diseased plants that the writer is not inclined to believe that this is an important source of spring infection.

SUMMARY OF WINTERING EXPERIMENTS

The writer's experiments and observations for the last three years seem to warrant the following conclusions as to the conditions under which the wildfire bacteria pass the winter:

1. They winter most successfully in situations where they are not subjected to keen competition from the growth of other organisms, principally in fairly dry situations; e. g., in cured leaves in the barn, leaves on plants standing in the field or thrown on the ground too late to rot, on boards, sash and dry fragments of pods.

2. They winter least successfully under conditions which are moist enough for the growth of competing organisms; e. g., in leaves in the ground or other situations where they decay, and in the soil.

PRACTICAL APPLICATION

In view of the conclusions just stated we may make the following recommendations to the grower:

1. If there has been wildfire in the field, plow under all leaves and stubble (before sowing the cover crop) as soon as the tobacco is removed. This will give all leaves and other harbingers of the pathogen an opportunity to become thoroughly decayed.

2. Do not leave diseased plants or suckers standing on the field during the winter.

3. Guard against the escape of infectious material from the barn where diseased tobacco has been hung. This is perhaps the most important source of spring infection.

4. If sash or plank have been stored in a barn where diseased tobacco is hung or if they have been used on an infected bed of the previous year, they should be sterilized.

5. If seed is saved from pods known to be free from disease, there is no advantage in sterilizing the seed.

6. If the above mentioned precautions are observed, there would seem to be no reason why a clean crop of tobacco cannot be grown on the same field which grew a diseased one during the previous year.

LITERATURE CITED

- ANDERSON, P. J., AND G. H. CHAPMAN. Tobacco wildfire in 1922. Mass. Agr. Exp. Sta. Bul. 213: 1-27. 1923.
CLINTON, G. P., AND F. A. McCORMICK. Wildfire of tobacco in Connecticut. Conn. Agr. Exp. Sta. Bul. 239: 365-423. 1922

DEPT. OF BOTANY,

MASS. AGR. EXP. STA.

HYPOXYLON POPLAR CANKER

ALFRED POVAH¹

WITH ONE FIGURE IN THE TEXT

INTRODUCTION

There are but three canker diseases of poplars for which the pathogen is known, viz., bacterial canker caused by *Micrococcus populi* Del. (1), European canker caused by *Dothichiza populea* S. & B. (2), and Cytospora canker caused by *Cytospora chrysosperma* (Pers.) Fr. (3). The first two are indigenous to Europe and up to the present time only the second has been introduced into this country. The third disease is recorded only for the United States, being very common in the Southwest. It also occurs in New York State (4). The fungus grows commonly as a saprophyte on twigs and logs along the beach at Evanston, Illinois. It seems rather strange that the fungus is not parasitic in Europe where it has been known for a long time.

The subject of this article is a new canker disease of poplar which was found by Dr. L. H. Pennington in Essex County, New York. During the summer of 1920 field studies of the disease were made in the Town of Lewis, Essex County, New York.

DISTRIBUTION OF THE DISEASE

In Essex County, the poplars—*Populus tremuloides* Michx., *P. grandidentata* Michx. and *P. balsamifera* L.—are noticeably affected with this disease which eventually kills them. The mortality runs as high as twenty-seven percentage. Dr. Pennington has found this same canker disease in Oswego County, N. Y.

In October, 1920, this disease was found by the writer on *P. tremuloides* in a thicket near Pontiac, Oakland County, Michigan. This patch of woods was in low, wet ground and the principal species of trees and shrubs were: *P. tremuloides*, *Salix* sp., *Acer rubrum* L. and *Ilex verticillata* (L.) Gray. Approximately one half of the quaking aspens were infected and fifteen to twenty per cent killed.

Mr. J. Elton Lodewick, in a letter to the author from Orono, Maine, writes: "All along the west bank of the Penobscot River between Orono and Oldtown the canker is quite common—not so much so as in Lewis

¹ Grateful acknowledgment is hereby made by the writer to Dr. L. H. Pennington for suggesting the problem to him and for aid in various ways.

(N. Y.), but still common enough to be noticeable. *P. tremuloides* seems to be most infected, though it may only appear that way because that (*P. tremuloides*) is more abundant than *P. grandidentata*. *P. balsamifera* which grows mixed with trembling aspen along the river shows no cankers."

From the fact that we have the disease recorded from Maine, northern and central New York and Michigan, it seems quite probable that careful search will show that it occurs throughout the north-eastern part of the United States.

DATA ON SAMPLE PLOT IN ESSEX COUNTY, NEW YORK

In August, 1920, a survey of a sample plot in Lewis, Essex Co., N. Y., was made to determine the extent and importance of the disease. The area selected was chosen with regard to the amount of poplar rather than the prevalence of the disease. It is believed, therefore, that it represents the average condition in that region in a stand where poplar is dominant. The arborescent species in the plot, given approximately in the order of their abundance, were: *P. tremuloides*, *P. balsamifera*, *Pinus Strobus* L., *P. resinosa* Ait. and *Betula alba* var. *papyrifera* (Marsh.) Spach. A plot measuring one chain square was staked out and all the poplars in it were calipered. In determining the diameter breast high (D. B. H.) the usual practice was followed, i. e., the one inch diameter class includes all individuals up to and including those 1.5 inches in diameter; the two inch class, 1.6–2.5 inches in diameter, etc.

TABLE 1.—Condition of *Populus balsamifera* in sample plot.

Number of trees	D. B. H. in inches	Trees in- fected	Trees not in- fected	Killed by canker	Still living	Dead other causes
2	2	0	2	0	1	1
2	3	1	1	0	1	1
2	4	1	1	0	2	0
4	5	0	4	0	4	0
3	6	0	3	0	3	0
13		2	11	0	11	2

A glance at tables 1 and 2 will show that there were thirteen balsam poplars and ninety trembling aspens in the plot. We note also (table 1) that only two of the former were infected and neither of these were killed by the Hypoxylon canker. This is interesting in that it agrees with what Mr. Lodewick has observed in Maine. Of the quaking aspens,

however, 33 trees, or 37 per cent, were infected and 24 trees, or 27 per cent, were killed by the disease.

Table 2 shows that there is a correlation between age and susceptibility, i. e., the smaller the tree, the more susceptible it is to the disease. This is shown more graphically in table 3.

TABLE 2.—*Condition of Populus tremuloides in sample plot.*

Number of trees	D. B. H. in inches	Trees in- fected	Trees not in- fected	Killed by canker	Still living	Dead other causes
13	1	6	7	6	3	4
18	2	9	9	7	8	3
21	3	7	14	5	16	0
15	4	6	9	3	12	0
14	5	3	11	1	13	0
7	6	2	5	2	5	0
1	7	0	1	0	1	0
1	8	0	1	0	1	0
90		33	57	24	59	7

TABLE 3.—*Relation between age and infection.*

Percentage infected	Percentage killed	D. B. H. in inches
10 0	7 5	2
7 5	5 5	3
6 5	3 5	4
3 5	1 0	5
2 0	2 0	6
0 0	0 0	7
0 0	0 0	8

We can also note that susceptibility decreases as the tree grows older, so that if a tree is not infected before it reaches a diameter of seven inches it is relatively safe from infection. Probably this is to be explained by the increasing thickness of the periderm.

DESCRIPTION OF THE DISEASE

The disease is a trunk canker that occurs either low down or high up on the tree. In one instance measurement showed the lesion to be thirty feet from the ground. It is rather interesting to note that thus far cankers have been found on the bole only and not on the branches. Quite commonly infection results in the formation of an eccentric stem due to the killing of the infected region and the continued growth of the healthy portion of the trunk.

At first the diseased regions appear as small, slightly discolored, sunken areas which increase in size until they coalesce forming a canker, delimited by vertical cracks. On large trees, the lesion attains a length of several feet before girdling the trunk. In one tree studied, the canker extended for ten feet encircling the stem except for a strip one and one-half inches in width. Ultimately the disease kills the tree by girdling it.

As the canker develops, the diseased region takes on a grayish color in which occur black patches due to the superficial periderm flaking off

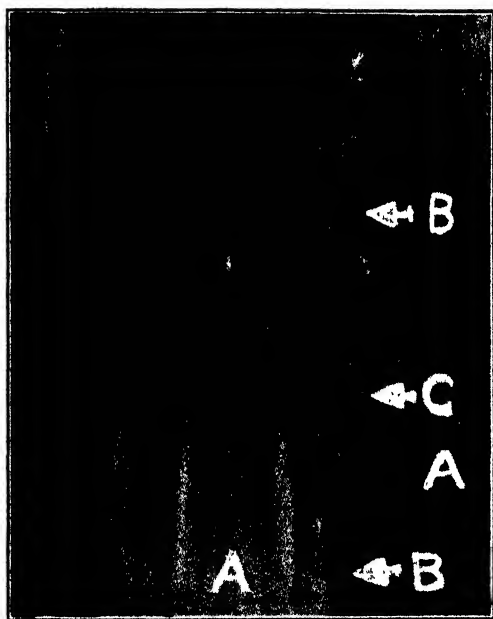


FIG. 1. Hypoxylon poplar canker after bark has been removed showing: A, normal wood; B, discoloration; C, mycelial fans.

and exposing the blackened cortex within. Scattered over the lesion are the stromata of *Hypoxylon pruinaum* (Klotzsch) Cke.¹

A transverse section of the diseased bark shows it to be composed of wide bands of a black, soft substance alternating with narrow, light-colored firm bands. The former are layers of cortex filled with the dark-brown hyphae of the fungus. The pale bands are layers of periderm which is not attacked because of its suberized walls. When the bark is peeled from a canker, the limits of the diseased area are shown

¹ Material was submitted to Dr. C. L. Shear who confirmed the author's identification.

by a blackening of the sap wood. The margin of this discoloration is irregular and vertically elongated in attenuated points between which are fans of whitish mycelium, resembling somewhat those of the chestnut bark disease, but differing in color.

Figure 1 shows the discolored wood and the fans of white mycelium on the sapwood of *P. grandidentata* after the bark has been removed.

DISCUSSION

The following synonymy of the fungus is given by Ellis and Everhart (5).

Sphaeria pruinata Klotsch.

Rosellinia pruinata Sacc.

Hypoxylon Holwayii Ell.

Hypoxylon pruinatum Cke.

According to these authors, *H. Holwayii* differs from *H. pruinatum* in that "surrounding the stroma and standing out obliquely like a coarse fringe, are short, coarse, black, bristle-like teeth, like the teeth of a *Hydnum* or *Irpex*. This curious growth also arises from the surface of the inner bark for some distance around the stroma, soon throwing off the epidermis and leaving the blackened surface of the inner bark exposed."

In our specimens the bristly appearance is found commonly but not constantly. In some cases it is due to the presence of small perithecia protruding from the inner bark in which they are formed, little or no stroma being present. Sometimes the same spine-like appearance is obtained by the breaking down of the perithecia leaving the jagged remnants of stroma and perithecial walls. In still other cases the dark teeth proved to be the more persistent parts of the inner bark left projecting after the softer part has been decayed.

It seems logical, therefore, to follow Ellis and Everhart in considering *H. Holwayii* as a synonym of *H. pruinatum*. Accordingly we have the range of the disease extended as the type material of *H. Holwayii* was collected in Iowa.

It is hard to account for the fact that this disease, which is common and striking in appearance has passed unnoticed up to the present time. Hartley and Hahn (6) in their paper on aspen diseases note three types of cankers. Type II might well be the *Hypoxylon* canker rather than of bacterial origin as these authors suggest. In figure 3 in their article, the broken tree shows plainly the mottled appearance so characteristic of the *Hypoxylon* Disease.

SUMMARY

A new canker disease of poplars has been found in New York and Michigan, and has been reported to the writer from Maine.

The pathogen is *Hypoxyylon pruinaum* (Klotsche) Cke.

A field study in Essex County, New York, showed that over 36 per cent of the trembling aspens were infected and over 26 per cent killed by the disease.

Younger trees are more susceptible than older ones. No infections were found on trees larger than six inches in diameter.

The disease is a trunk canker and ultimately kills the trees by girdling them.

The lesion is manifest by slight discoloration of the bark and delimited by vertical cracks.

The sapwood is blackened, the discoloration extending vertically in attenuated points. On the darkened area are fans of whitish mycelium.

DEPARTMENT OF BOTANY,
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EVANSTON, ILLINOIS.

LITERATURE CITED

- (1) STEVENS, F. L. Fungi which cause plant disease. p. 21. New York, 1913.
- (2) RANKIN, W. H. Manual of tree diseases. p. 301. New York, 1918.
- (3) LONG, W. H. An undescribed canker of poplars and willows caused by *Cytospora chrysosperma*. Journ. Agric. Res. 13: 331-345. 1918.
- (4) POVAH, A. H. W. An attack of poplar canker following fire injury. Phytopath. 11: 157-165. 1921.
- (5) ELLIS AND EVERHART. North American Pyrenomycetes. p. 639. Newfield, New Jersey, 1892.
- (6) HARTLEY, G., AND HAHN, G. C. Notes on some diseases of aspen. Phytopath. 10: 141-147. 1920.

parabasal body was 1.5 microns, from the parabasal body to the anterior margin of the nucleus 1.8 microns, and from the posterior margin of the nucleus to the posterior tip of the body 8.8 microns. The length of the flagellum was very variable. Sometimes it exceeded the length of the rest of the body (See figure 6), but more often it was rather short. Occasionally leishmania forms were observed.

Figures 1 to 6 show typical flagellates from smears of the latex of the milkweed. Several successive stages of division are included.

Sections were prepared of the tissue of the seed pod, where the herpetomonads were very numerous. The individuals were so crowded together in the latex tubes that they were difficult to study, but frequently at the edges of the section and elsewhere very favorable views of the organisms were obtained.

NOMENCLATURE

A similar species was found in 1916 by Migone (3) in Paraguay in the latex of *Araujia angustifolia* (Gris.), a common milkweed. He gave it the name *Leptomonas Elmassiani*. Later França (1) studied his material of this species and compared it with *L. Bordasi* and *L. Davidi*, both of which are larger in size. His measurements are shown in table 2.

The flagellate from the Baltimore milkweed corresponds very well in size and morphological characteristics with the measurements here given by França for *L. Elmassiani* Migone. This name should be written *Herpetomonas elmassiani* (Migone), for the genera *Leptomonas* and *Herpetomonas* were united in 1884 by Bütschli, the first reviser, under the name of *Herpetomonas*. Perhaps for the present the flagellate from the Baltimore milkweed may be considered to be *Herpetomonas elmassiani* (Migone), since morphologically and physiologically it seems indistinguishable from the species first observed in Paraguay by Migone.

SUSPECTED INSECT CARRIER

A red and black hemipterous insect, *Oncopeltus fasciatus* (Dall.) was found closely associated with the infected plants. It is suspected of being the insect carrier of the flagellates. Plants on which it was found were, with but a single doubtful exception, positive. It was moreover associated with the majority of the infected groups studied, at the time they were examined. Both adults and nymphs of this species contained at times in their intestinal tracts flagellates such as are represented in figures 7 to 10. It will be noted that these flagellates are larger and more variable in size than the organisms in the plant, but that they are very

similar in general appearance. Their short forms are well within the range of size of the plant form.

In the late summer when these flagellates were first found, the infected plants were decidedly yellower than the seedlings, or uninfected second year plants. The yellowing may have been due to the flagellosis, as the latex was modified from a smooth creamy fluid to a watery emulsion of organisms.

Since the flagellates were not found until the last of August, it was not possible to carry out suitable transmission experiments this season to determine the exact standing of *Oncopeltus fasciatus* (Dall.) as a carrier of the flagellate, nor to attempt mechanical transmission from infected to uninfected plants. No effort was made to grow the organism in pure culture or to study its life history in detail. My studies on the effect of *Herpetomonas elmassiani* (Migone) on the health of the host plant are also necessarily incomplete, but because of the general interest in the subject of protozoa in plants it seems desirable to report the discovery of these organisms in the United States at this time.

SUMMARY

A flagellate infection of milkweed (probably *Asclepias syriaca* L.) was discovered during the autumn of 1923 near Baltimore, Maryland. The flagellates correspond fairly closely to those properly known as *Herpetomonas elmassiani* (Migone), described in 1916 by Migone in Paraguay. So far as is known this is the first report of such organisms in the United States.

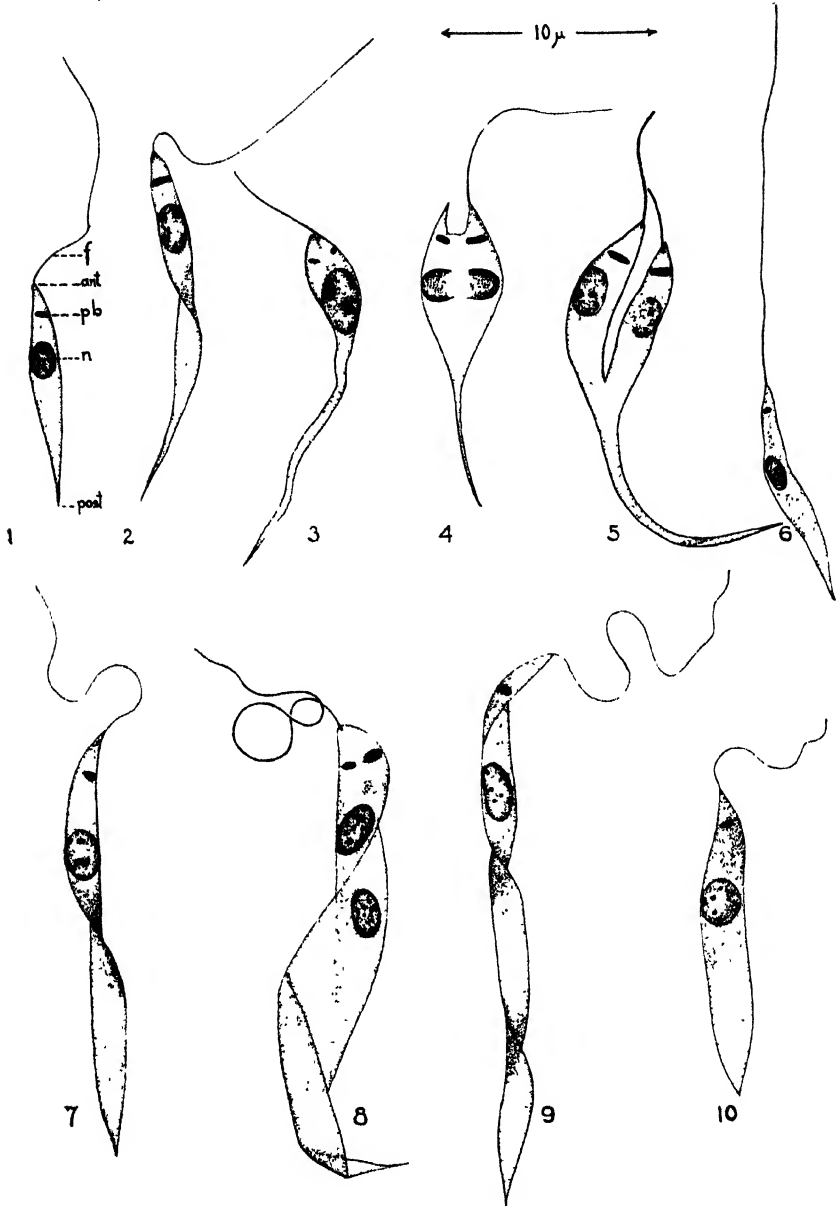
A red and black hemipterous insect, *Oncopeltus fasciatus* (Dall.) is suspected of carrying the flagellates from plant to plant.

LITERATURE CITED

- (1) FRANCA, C. Sur deux Phytoflagellés. (*L. Elmassiani* Migone et *L. Bordusi* sp. n.). Annales de la Société Belge de Médecin Tropicale 1: (No 2), 1-10. 1921.
- (2) LAFONT, A. Sur la présence d'un parasite de la classe des Flagellés dans le latex de *Euphorbia pilulifera*. Compt. Rend. Soc. Biol. Paris 66: 1011-1013. 1909.
- (3) MIGONE, L. E. Un nouveau flagellé des plantes: *Leptomonas Elmassiani*. Bull. Soc. Path. Exot. 9: 356-359. 1916.

DESCRIPTION OF FIGURES

Figures 1-6. *Herpetomonas elmassiani* (Migone) from the latex of plants of a milkweed growing near Baltimore, Md. $\times 3000$. *f.* flagellum, *ant.* anterior end of body, *p. b.* parabasal body, *n.* nucleus, *post.* posterior end of body. 1 and 2. Typical flagellates showing approximate position of organelles before division. The twist in the body of the second example is very characteristic. 3. Beginning of division. Parabasal body double. 4. Nucleus dividing. Cleft in cytoplasm. 5. Division of the organelles completed. Division of the body in progress. 6. A small individual with unusually long flagellum. Figures 7 to 10. Flagellates from the intestine of *Oncopeltus fasciatus* (Dall.). $\times 3000$. 7. Flagellate of about average size, showing characteristic twist in the ribbon-like body. Except in its greater size it much resembles the flagellates from the latex of the milkweed. 8. Broad form in which division of the parabasal body and nucleus has already been completed. At this stage it is characteristic that one daughter nucleus should be farther from its parabasal body than the other. 9. A long form with more twists than it is usual to see among the plant flagellates in the latex smears. 10. A rather short individual, well within the length range of *Herpetomonas elmassiani* (Migone).



FLAGELLATES

BOTRYTIS CINEREA IN ALASKA

J. P. ANDERSON

WITH PLATE III

The importance of *Botrytis cinerea* Pers. as a plant pathogen in Alaska seems to justify a somewhat more detailed statement as to its occurrence and host relations than was contained in the writer's earlier publications on the fungi and plant diseases (1, 2, 3) of that territory. Observations extending over a period of more than nine years, much of which has been spent in the practical cultivation of ornamental plants, truck crops, and small fruit in South-east Alaska, has convinced the writer that *B. cinerea* is by far the most serious fungous parasite in that region. It is well within the observed facts to state that more than three-fourths of all the fungous injury to cultivated plants in South-east Alaska is caused by Botrytis.

REASONS FOR THE PREVALENCE OF BOTRYTIS

The climate of the Pacific Coast region of Alaska is characterized by mild winters and cool summers accompanied by much cloudy and rainy weather. At Juneau, where the writer has spent most of the last seven years, the average annual precipitation is 76.5 inches, June being the driest month and October the wettest. The warmest month, July, has a normal average temperature of 57.9° F. The cool moist climate seems to be especially favorable for the development of Botrytis. While it occurs at all seasons and is liable to do damage during long spells of cool rainy weather, even in midsummer, it reaches its maximum development in the fall, the period of greatest precipitation. These observations of the writer as to the relation of temperature and moisture to the development of Botrytis agree with those of Stevens and Wilcox (4, 5) on strawberries and of Thomas (6) on tomatoes.

The influence of dampness is well illustrated by the behavior of the fungus in the greenhouse. During long periods of cloudy weather with little or no sunshine the air in the greenhouse becomes saturated with moisture, and if fires are not started so as to dry the atmosphere most of the plants will soon be ruined. The writer has found that the best methods of control are by drying the air and removing the parts of plants that are infected or liable to become infected.

METHOD OF INFECTION

The writer has never observed a single instance in which green vigorous leaf tissue has been directly infected by spores of *B. cinerea* even when spores were so numerous that thousands must have lodged on every leaf. Dying plant parts are readily infected as are mature fruits and the petals of flowers. Under very favorable conditions for the fungus the petals are often infected before the flowers open, causing the buds to decay.

After a vigorous mycelium has been developed on a flower petal or other susceptible plant part it spreads readily to healthy tissue with which it may come in contact. No species of flowering plant seems to be immune from its ravages, especially under greenhouse conditions. Even liverworts and mosses become infected where infected portions of flowering plants fall on them. Conidia develop rather sparingly on Bryophytes and Pteridophytes.

HOST RELATIONS

Among Spermatophytes, although no species is immune, there is considerable difference in susceptibility. Fruits of the blueberries (*Vaccinium*) are infrequently attacked, while the fruits of the salmonberry (*Rubus spectabilis*) are sure to become covered with the gray mold characteristic of Botrytis. The earlier ripening fruits may not be attacked for a week or two but conidia from the early fruits become abundant enough to attack the later fruit soon after ripening. It is interesting to note that as the fruit dries the Botrytis has a tendency to disappear and other fungi may develop, especially *Cladosporium herbarum* (Pers.) Lk. The fruit of the cultivated strawberry (*Fragaria sp.*) is very generally attacked by Botrytis species. Dr. N. E. Stevens of the Bureau of Plant Industry, has reported to the writer that during August, 1922, more than two-thirds of the decayed strawberries found by him in the fields at Haines and Sitka, and in the market at Juneau, contained Botrytis alone.

Although the writer has collected Botrytis on more than one hundred hosts he is convinced that a single species is common to all. This is shown by the fact that, whenever infected parts of one host species come in contact with a second host, infection of the second host by the fungus readily occurs. This cross-infection is very common and is illustrated in the accompanying plate.

GENERA OF PLANTS ON WHICH BOTRYTIS HAS BEEN COLLECTED IN ALASKA

These are all represented by specimens in the writer's collection at Juneau. Some of the genera are represented by more than one species.

Spermatophytes—*Abutilon*, *Agave*, *Amelanchier*, *Amorphophallus*, *Antirrhinum*, *Apium*, *Artemisia*, *Asparagus*, *Begonia*, *Bellis*, *Brassica*, *Calceolaria*, *Calendula*, *Callistephus*, *Chamaenerion*, *Campanula*, *Cheiranthus*, *Chrysanthemum*, *Citrus*, *Coleus*, *Coreopsis*, *Cucumis*, *Cuphea*, *Dahlia*, *Dianthus*, *Dimorphotheca*, *Echinopanax*, *Erigeron*, *Eschscholtzia*, *Euphorbia*, *Fragaria*, *Fuchsia*, *Geranium*, *Gladiolus*, *Godetia*, *Grevillea*, *Grossularia*, *Helitropium*, *Hibiscus*, *Hippeastrum*, *Hosta* (*Funkia*), *Hydrangia*, *Iberis*, *Lactuca*, *Lantana*, *Lathyrus*, *Ligularia* (*Farfugium*), *Linaria*, *Lobelia*, *Lonicera*, *Lychnis*, *Lycopersicum*, *Matthiola*, *Melissa*, *Mimulus*, *Myrsiphyllum*, *Nepeta*, *Nicotiana*, *Oenothera*, *Oxalis*, *Papaver*, *Pelargonium*, *Phaseolus*, *Phlox*, *Pisum*, *Poa*, *Potentilla*, *Primula*, *Prunus*, *Rheum*, *Rhinanthus*, *Ribes*, *Rosa*, *Rubus*, *Sambucus*, *Senecio* (*Cineraria*), *Solanum*, *Tagetes*, *Thymus*, *Tradescantia*, *Tropaeolum*, *Tulipa*, *Vaccinium*, *Vicia*, *Viola*, *Zebrina*, *Zantedeschia* (*Calla*), *Zinnia*.

Pteridophytes—*Athyrium*, *Cyrtomium*, *Nephrolepis*.

Bryophytes—*Lunularia*.

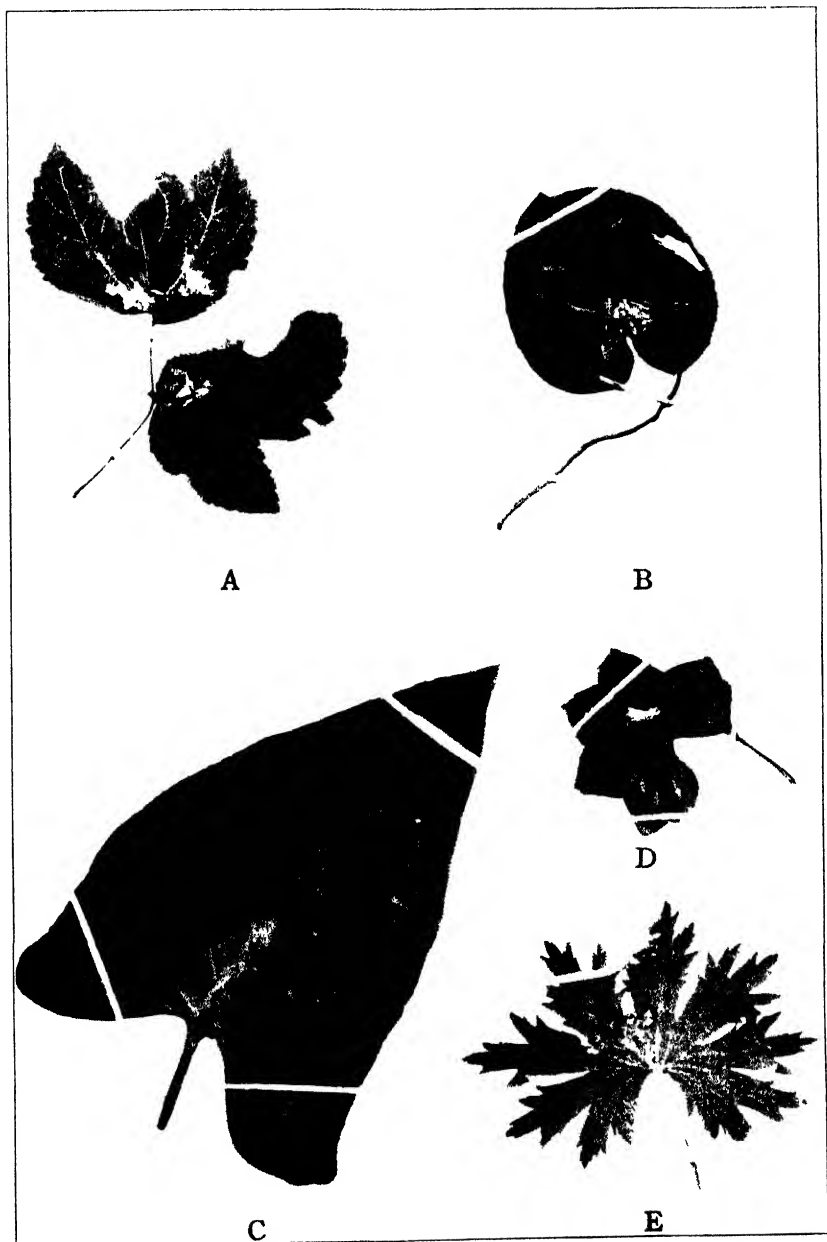
Botrytis cinerea Pers. is supposed to be the conidial stage of *Sclerotinia fuckeliana* (DeBy.) Fcl. but the writer has never found the ascigerous stage, and has found sclerotia only a few times. Several years ago sclerotia developed abundantly on some cabbage in a cellar. Some of these were brought into the greenhouse and later developed dense masses of conidia but no apothecia.

SUMMARY

The cool damp climate of the Pacific Coast region of Alaska is especially favorable for the development of *Botrytis cinerea*, which is much the most destructive fungus to living plants observed there.

Although generally considered a weak parasite and certainly not capable of infecting vigorous green leaf tissue by conidia, it grows readily into healthy tissue from previously infected weaker portions.

It attacks nearly all species of plants but there is a difference in susceptibility of various species. There seems to be but one common species in Alaska which passes readily from one host to another. The ascigerous stage is seldom or never formed in Alaska but sclerotia are sometimes found.



BOTRYTIS CINEREA ON VARIOUS HOSTS

It is more destructive to garden and greenhouse plants than to native species. Removing affected plants or parts of plants, together with drying the atmosphere, are the most efficient methods of control in the greenhouse.

LITERATURE CITED

- (1) ANDERSON, J. P. Fungus diseases. Rept. Alaska Agric. Exp. Sta. 1914. p. 26, 27. 1915.
- (2) ———. Plant diseases. Rept. Alaska Exp. Sta. 1915: 39-41. 1916.
- (3) ———. Some Alaska fungi. Proc. Iowa Acad. Sci. 27: 99-108. 1922.
- (4) STEVENS, N. E. Rots of early strawberries in Florida and southern California. Amer. Jour. Bot. 9: 204-211. 4 fig. 1922. Literature cited, p. 211.
- (5) ———, AND R. B. WILCOX. Further studies on the rots of strawberry fruits. United States Dept. Agric. Bull. 686. 14 p. 1918. Literature cited, p. 14.
- (6) THOMAS, ROY C. Botrytis rot and wilt of tomato. Ohio Agric. Exp. Sta. Monthly Bull. 6: 59-62. 3 fig. 1921.

DESCRIPTION OF PLATE III

A. Leaf of *Rubus spectabilis* infected with *Botrytis cinerea* from fallen floral parts of *Epilobium angustifolium*, collected in September, 1922. B. Cyclamen infected from Fuchsia. C. Calla infected from *Pelargonium domesticum*. D. *Pelargonium pellatum* infected from *Senerio cruentus*. E. *Pelargonium domesticum* infected from *Begonia semperflorens*. B, C, D, and E are from artificial inoculations made by placing infected portions of plants on sound, healthy leaves of other species. All from photographs made by Winter and Pond Company.

THE RELATION OF TEMPERATURE AND HUMIDITY TO TOMATO LEAF SPOT (*SEPTORIA LYCOPERSICI* SPEG.)

FRED J. PRITCHARD AND W. S. PORTE

WITH PLATE IV AND NINE FIGURES IN THE TEXT

INTRODUCTION

As tomato leaf spot, or blight (Pl. IV), causes an average annual loss of approximately 250,000 tons in the yield, and corresponding reductions in the quality, of commercial tomatoes in the United States, the relation of temperature, humidity, or any other factor, to its development and control is both interesting and important to the tomato grower and the manufacturer of tomato products. The present paper is confined to a discussion of the temperature relations of the parasite and host, and the temperature and humidity relations of the disease, with suggestions for leaf spot control based on temperature relations of the parasite.

Tomato leaf spot is quite widely distributed east of the Rocky Mountains and is common and destructive in the Middle Atlantic and Middle Western States, but is apparently absent in the Pacific Coast region. Its distribution has usually been assumed to be conditioned by atmospheric humidity. In fact, we know from the inoculation of more than a hundred thousand tomato plants in our selection experiments for resistance to leaf spot that the number of infections always increases with the relative humidity of the air. However, the fact that leaf spot is absent on the Pacific Coast and is only sparingly present in the North Atlantic and Gulf States, where the relative humidity is very high, would indicate that temperature or some other factor plays an important part in its distribution. We have therefore investigated the temperature relations of the leaf spot fungus (*Septoria lycopersici*) in order to determine to what extent they affect its development and in what way, if any, they may be made use of in the application of control measures.

MATERIAL AND METHODS

The temperature relations of the fungus in culture were determined by means of a Paul Altmann's Incubator. This apparatus consists of 20 chambers, each provided with a pan of water for maintaining high humidity and a thermometer for reading the temperatures. A circulating water system in which the water is heated by electric coils controlled by thermostats at one end of the series and cooled by ice at the other is used



PLATE I, FIG. 1. Septoria leaf spot on tomato leaves. Spots on leaf at left about natural size, spots at right enlarged to show pycnidia (spore pustules)



PLATE I, FIG. 2. Effect of Septoria leaf spot on tomato crop. Plants in field at left nearly destroyed by leaf spot; those in field at right healthy.

to keep the chambers at different relatively constant temperatures. The apparatus was kept in an insulated room cooled to about 22° C. by means of ice. The temperature of each chamber remained fairly constant during the experiments, usually varying less than 1° C., but the difference between the temperatures of adjoining chambers varied from 1° to 5° and averaged approximately 2°.

The temperatures were read daily and averaged for each chamber. The experiments on the optima and maxima were run from 2 days to 2 weeks, depending on the rapidity of growth, those on the minima, one month. The average temperatures obtained by this method are therefore only approximately correct but are accurate enough for most practical purposes.

The culture media used in the experiments on growth temperatures were cornmeal and cornmeal agar; in the experiments on sporulation temperatures, fairly dry cornmeal.

TEMPERATURE RELATIONS OF SEPTORIA LYCOPERSICI IN CULTURE

The following growth temperatures were obtained for *Septoria lycopersici* in culture: minimum 35°, optimum 77°, and maximum 94° F. In flask cultures the lowest temperature at which growth was visible by means of the unaided eye was 42.8° but in hanging drops it was discernible by means of the microscope at 35°. As scarcely any growth was obtained at approximately 43° F. in a month's time, very little growth would be made by this fungus outdoors in the spring of the year below 45°. Although the fungus grew best at 77°, it grew well between 54° and 82°.

There was considerable difference between the range of temperature for growth and the range for sporulation. Although the optimum for the latter was the same as for growth, viz. 77°, the minimum was 59° and the maximum 80.5°. The relation of these sporulation temperatures to the development and distribution of leaf spot and to means for its control will be discussed in another part of this paper.

TEMPERATURE RELATIONS OF THE HOST

The optimum range of temperatures for the growth of tomato plants determined by Clayton¹ (2) is 77° to 86° F. Although these temperatures apparently give the best vine growth, they are higher than are commonly

¹ The temperatures determined by Clayton were soil temperatures but the average temperatures of the first few inches of soil do not differ materially from the temperatures of the air for the same locality.

used for growing tomatoes under glass. It would therefore seem that lower temperatures are more favorable for the production of fruit.

The optimum temperature for the production of tomato fruit can be determined approximately, at least, from statements of experienced gardeners and from weather bureau and field records on temperatures and yields. For greenhouse crops of tomatoes, Iggulden (4) recommends a temperature of 50° to 55° by night and 60° to 65° by day; Greene (3) 60° at night and 70° or 75° during the day. About 60° F. is also recommended by the "Fruit, Flower, and Vegetable Trades' Journal." (1) These temperatures are somewhat lower than preferred by Watts (6), viz.

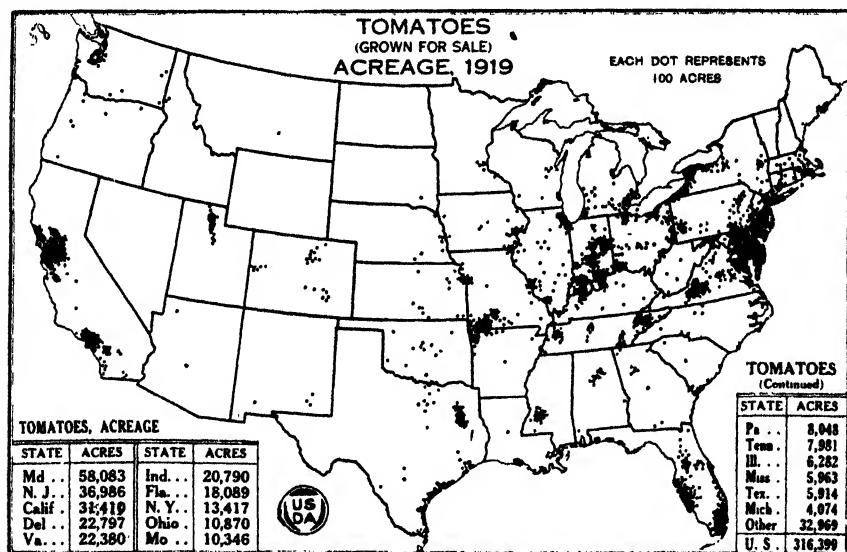


FIG. 1. Areas of tomato production for commercial purposes.

80° to 90° during the day and 15° to 20° lower at night, but approximately the same as recommended by Mayer.¹ Mayer, who is in charge of the (U. S. Government) Experimental Greenhouses at Arlington, Virginia, has had much experience in growing tomatoes at a considerable range of temperatures and is very skillful in growing tomatoes and other crops under glass. His recommendation of 60° to 65° at night and 65° to 70° in the daytime as the best for forcing tomatoes is probably not far from the optimum.

¹ This recommendation by August Mayer was given to the writers verbally.

TABLE 1.—*Relation of temperature to yield of tomatoes.*

State	Average yield, tons per acre from 1918 to 1921	Average daily tem- perature F. during growing season	growing season	Average length of growing season	Average date of last killing frost in spring	Mean monthly temperature in the principal tomato canning regions of each state†							Average date of first killing frost in autumn
						Apr. °F.	May °F.	June °F.	July °F.	Aug. °F.	Sept. °F.	Oct. °F.	
Utah	10 0	65	5/20-10/5	4/23	45	55	65	70	70	60	50	35	10/18
Colorado	7 4	65	5/25-9/25	4/28	46	55	60	70	70	60	50	36	10/5
Washington	7 1	57	5/1-11/1	3/21	45	55	56	60	63	55	50	41	11/22
New York	7 1	65	5/20-10/5	5/3	45	55	65	70	68	62	51	39	10/20
Oregon	6 9	59	4/20-11/1	3/17	50	55	60	65	65	60	50	45	11/16
California	5 9	62	4/1-11/1	4/8*	55	60	65	66	66	62	60	52	11/15
				2/16**									
Ohio	5 3	69	5/20-10/5	4/20	50	61	68	74	71	65	53	42	10/15
Idaho	5 2	64	4/25-9/25	3/23	50	55	65	70	70	60	50	40	10/5
Connecticut	4 8	66	5/15-10/10	4/15	45	57	66	71	69	63	51	41	10/25
Michigan	4 8	67	6/1-10/5	5/1	46	57	66	71	70	63	51	39	10/14
Massachusetts	4 7	65	5/20-10/5	4/22	45	56	65	70	67	61	49	40	10/20
New Jersey	4 4	69	5/10-10/15	4/10	50	60	70	74	73	67	57	44	11/1
Indiana	4 2	72	5/10-10/1	4/10	53	64	72	76	75	68	55	44	10/17
Illinois	4 2	71	5/15-10/1	4/15	51	62	71	76	75	68	55	40	10/15
Pennsylvania	4 1	67	5/20-10/10	4/22	49	60	66	74	70	65	54	40	10/25
Minnesota	4 0	66	6/1-9/25	5/7	45	56	66	71	67	60	47	32	10/5
Iowa	3 7	70	5/20-10/1	4/22	50	59	70	75	74	65	53	38	10/12
Kansas	3 7	74	5/15-10/1	4/15	55	65	73	78	78	70	57	42	10/15
Oklahoma	3 7	75	5/5-10/20	4/5	60	67	76	81	81	74	62	50	11/1
North Carolina	3 6	73	5/10-10/20	4/8	58	68	75	78	77	71	60	50	11/1
Delaware	3 4	69	5/5-10/20	4/6	52	62	71	75	74	68	58	45	11/1
Louisiana	3 4	74	2/25-11/15	1/24	68	75	82	82	82	79	70	60	12/1

TABLE I—Continued.

State	Average yield, tons per acre from 1918 to 1921	Average daily tem- perature F. during growing season	Average length of growing season	Average date of last killing frost in spring	Mean monthly temperature in the principal tomato canning regions of each state†							Average date of first killing frost in autumn	
					Apr. °F.	May °F.	June °F.	July °F.	Aug. °F.	Sept. °F.	Oct. °F.		Nov. °F.
Maryland	3.4	70	5/5 -10/20	4/8	53	63	72	76	75	69	57	46	11/1
Mississippi	3.4	75	4/5 -10/25	3/6	66	73	80	81	81	76	65	55	11/7
Tennessee	3.3	73	5/5 -10/10	4/5	58	68	75	78	76	70	60	49	10/22
West Virginia	3.3	68	5/20-10/10	4/20	51	61	70	73	71	65	55	40	10/23
Wisconsin	3.3	66	6/1 -10/1	5/10	43	54	65	71	68	60	48	35	10/8
Virginia	3.2	72	5/15-10/15	4/15	56	66	74	78	77	69	58	47	11/2
Nebraska	3.0	72	5/20- 9/20	4/21	52	61	71	76	75	66	54	38	10/1
Texas	3.0	75	4/5 -11/1	3/5	65	72	80	82	82	77	66	57	11/13
Alabama	2.9	75	5/1 -10/20	4/1	62	70	77	80	79	74	62	52	11/1
Kentucky	2.9	72	5/5 -10/5	4/6	56	66	74	77	76	70	57	46	10/21
Arkansas	2.8	73	5/5 -10/15	4/5	59	66	75	80	79	70	60	49	10/28
Georgia	2.7	74	4/25-10/25	3/25	60	70	78	80	78	73	62	51	11/5
South Carolina	2.7	74	4/10-11/5	3/10	64	73	77	82	80	76	65	55	11/15
Missouri	2.6	73	5/5 -10/15	4/8	57	65	74	79	78	70	59	47	10/25
New Mexico	2.6	75	5/5 -10/5	4/5	60	70	76	80	80	71	60	50	10/15

† The data for Florida is omitted because it can not be put into this table but its omission does not alter the results.

* Los Angeles.

** Sacramento.

The optimum temperature for the production of field crops of tomatoes has been determined from the average monthly temperatures of the tomato areas of each state (Mo. Wea. Rev. V. 49, No. 11, 1921 and Year Book of the U. S. D. A. 1921, p. 462) as shown in figs. 1-7. The average length of the growing season was estimated from the average dates of the last killing frost in the spring and the first killing frost in the autumn (Climatology of the U. S. Bull. Q, plates 19 and 20) and the average yields of tomatoes per acre (1918-1921) were calculated from the data in Wea. Crops and Markets, V. 1, No. 6, Feb. 1922, p. 116. These results are summarized in table 1.

As shown by the above table, the average daily temperature during the growing season varied from 57° in the State of Washington to 75° in Oklahoma, Mississippi, Texas, Alabama and New Mexico. The average daily temperature of all these localities is approximately 69° F. but even the highest daily temperature, viz. 75°, is lower than the optimum range for vine growth (77°-86°) found by Clayton (2).

With one exception, viz. Ohio, all the average yields of 5 tons or more per acre were obtained where the average daily temperature during the growing season was 65° or less. There are a few cases of low temperatures where relatively low yields were obtained, viz. Minnesota, Wisconsin, and West Virginia, but in at least two of these states yields are often reduced by frosts. Pertinent at this point is the following quotation from Climatology of the United States, Bulletin Q, p. 33: "Light frost during the latter part of August is not an unusual occurrence over Michigan, Wisconsin, Minnesota, the Dakotas, and Montana." In fact, the coldest September of record for Wisconsin was in 1918 (a year of this yield period) and the yield of tomatoes for the state averaged only 0.9 tons per acre.

In correlation table 1 made from the above data the relation of temperature to yield can be seen more clearly:

In table 2, a high inverse correlation exists between yield of tomatoes per acre and average daily temperature during the growing season. Owing to the wide area on which these tomatoes were grown, however, and the differences in soil fertility, soil moisture, and climatic factors other than temperature, it is uncertain how much of this correlation is due to the effect of temperature on yield and how much to some other factor, particularly soil fertility, incidentally correlated with temperature. For this reason the coefficient of correlation was not calculated. However, it would seem that temperature rather than soil fertility is the predominating cause of this correlation, since only medium to low yields

were obtained on the rich soils of Illinois, Iowa, Kansas, and Nebraska, where medium high temperatures prevail. Moreover, in regions where the fertility of the soil is low fertilizer is usually added to make up the shortage. This would tend to overcome the effects that would otherwise arise from differences in soil fertility.

As shown by table 2, the highest yields were obtained at or below 65° and the lowest at or above 72°. Moreover, it would appear from this table that 65° is the optimum temperature for the production of tomatoes.

TABLE 2—*Correlation between yield of tomatoes per acre and average daily temperature during the growing season.*

Yield per acre tons	Average daily temperature																
	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
2 5-2 9																	
3 0-3 4										1		1	1	1		1	2
3 5-3 9																	2
4 0-4 4										1	1		1		1	1	1
4 5-4 9									1	1	1						
5 0-5 4								1					1				
5 5-5 9						1											
6 0-6 4																	
6 5-6 9			1														
7 0-7 4	1								2								
7 5-7 9																	
8 0-8 4																	
8 5-8 9																	
9 0-9 4																	
9 5-9 9																	
10 0-10 4									1								

It is not surprising that the optimum temperature for vine growth is different from that for yield of fruit, for excess vine growth usually results in the development of very little pollen and a poor set of fruit. As is commonly known, a good set of fruit is quite as essential as favorable growth factors for the production of high yields.

RELATION OF TEMPERATURE TO THE DEVELOPMENT OF THE DISEASE

It was shown by Pritchard and Porte (5) that in tomato plants susceptibility to leaf spot is correlated with rapidity of growth. Although differences in rapidity of growth in these experiments were caused by different kinds and quantities of fertilizer, susceptibility to leaf spot was independent of the kind or quantity of fertilizer used except as it

affected growth. Within certain limits therefore it is quite likely that rapid growth induced by temperature would have a similar relation toward leaf spot. Since the optimum range of temperatures for the growth of the tomato plant is 77° to 86° and the optimum range for the growth of the fungus 54° to 82° , the optimum for the disease would apparently occur where these ranges overlap.

RELATION OF TEMPERATURE TO THE DISTRIBUTION OF LEAF SPOT

It is evident from an examination of fig. 5 that the percentage losses from tomato leaf spot are heaviest in the Middle Atlantic and Middle Western States. Within this area leaf spot reaches its maximum development in the states bordering the Atlantic Coast and decreases gradually westward. It is of very little importance in the northern and southern tiers of states and is apparently absent in the Pacific Coast region.

Within the Middle Atlantic and Middle Western States leaf spot develops most rapidly in July, August, and the fore part of September. The chief development occurs in a temperature belt of 73° to 78° F. (figs. 4-5). This probably explains why leaf spot does not appear in the tomato regions beyond the Rocky Mountains as the temperatures are too low. It also explains why it is relatively unimportant in New York, Michigan, Wisconsin, Minnesota, and the Dakotas. The temperature conditions in the Gulf States would seem to inhibit the development of pycnidia and spores of *Septoria lycopersici* in the fields before June, unless the plants were infected in hot beds, cold frames, or other sheltered places. Although the mean monthly temperature for April in central Georgia, Alabama, Mississippi, and Texas is 65° , pycnidia and spore development would take place very slowly at this temperature, which is little above its minimum, viz. 59° F. In May the mean monthly temperature for this area is more favorable, viz. 73° (fig. 2), but in June it is approximately 80° (fig. 3), while the maximum temperature for sporulation is 80.5° . In July and August (figs. 4-5) the temperature is still higher in these states. Because of these cool spring and high summer temperatures the leaf spot fungus has little opportunity to sporulate and spread. In September (fig. 6) the mean monthly temperature for this area is 75° but in October it is only 65° F. (fig. 7). Hence the failure of *Septoria lycopersici* to cause much damage in the Gulf States is apparently due to the shortness of favorable periods of temperature for the successful development of pycnidia and spores.

RELATION OF RELATIVE HUMIDITY TO THE DISTRIBUTION OF LEAF SPOT

A belt of uniformly high relative humidity along the coasts of the United States averages about 75 to 80 per cent at all seasons of the year. A somewhat similar amount occurs in the Great Lakes region. From the Great Plains eastward to the Atlantic Coast the amount varies between 70 and 75 per cent without much seasonal variation.

It is obvious from an examination of the humidity charts for July (figs. 8-9),¹ which also show percentage losses from leaf spot,² that New Jersey, Delaware, Maryland, and Virginia have a higher relative humidity than states farther west in the same temperature belt; also that North Carolina, Kentucky, and Tennessee have a higher relative humidity than Illinois, Iowa, Missouri, and Kansas. These relative humidities are correlated with leaf spot losses. *Septoria* leaf spot therefore develops best in a very moist atmosphere but its distribution, as shown by its absence on the Pacific Coast and only sparse presence along the Gulf of Mexico and North Atlantic Coast, is conditioned more by temperature than by humidity.

EFFECT OF TEMPERATURE ON THE CONTROL OF LEAF SPOT

Since the high minimum sporulation temperature (59° F.) of *Septoria lycopersici* greatly retards its development in the spring, the growing of earlier crops of tomatoes offers at least a partial means of escaping it. Some of the large companies manufacturing tomato products have already begun the growing of earlier crops by the use of southern-grown plants. Although the use of such plants is attended with the danger of introducing other diseases, especially wilt, it insures an earlier start for the crop, a shorter period of leaf spot attack, and a cooler temperature in the early part of the season when the first blossoms form. Cool temperatures appear to check vegetative growth and induce fruiting. Fruit set in the first cluster also checks vine growth. Hence this practice of using southern-grown plants seems sound, but if sufficient precautions are not taken it may result in bringing in plants infected by leaf spot and early blight, which would cause an earlier outbreak of these diseases.

The protection of the late crops of tomatoes from leaf spot would seem to depend on measures for preventing the overwintering of the fungus. Because of the retarding effect of spring temperatures on the sporulation of *Septoria lycopersici*, leaf spot does not usually appear on tomatoes

¹ From Mo. Wea. Rev. 50: 575-581. 1922.

² Calculated from Plant Disease Survey Records (Plant Disease Bulletins).

in the field in the Middle Atlantic and Middle Western States before the middle or latter part of June. Effective measures for preventing its overwintering would greatly reduce the number of early infections in the field and retard its spreading. Thoroughly plowing under all the old tomato vines in the fall or early spring and planting the land to a non-cultivated crop without bringing any of the vines to the surface while preparing the seed bed will destroy the leaf spot fungus on them. Experimental data, which will be published later, show that this fungus can not live in the soil.

As the leaf spot fungus also infects potatoes, eggplants, horse nettle, Jimson weed, and a number of other wild Solanums and probably other weeds, all of these hosts should be kept off tomato land, as otherwise the fungus would overwinter on them.

The avoidance of tomato seedlings grown in hot beds, cold frames, or other sheltered places infested by *Septoria* or brought from unknown sources also helps to prevent the spread of the disease. In fact, the seed bed, because of its sunny location, well manured soil, and protection from winds, is warmer than the exposed fields and consequently is often the source of early infections, although the disease may not be apparent when the plants are set out.

Because of the temperature limitations on the production of spores and the consequent late appearance of the disease in the fields, except when carried there from the seed bed, such means as outlined for preventing the development and spread of leaf spot can be made effective without much expense.

LITERATURE CITED

- (1) ANON.—The A B C of tomato growing. Fruit, Flower, and Vegetable Trades' Jour., Jan. 20, 1923, p. 61 (A long series of articles on this subject).
- (2) CLAYTON, EDWARD F. The relation of temperature to the Fusarium wilt of tomato. Amer. Jour. Bot. 10: 71-88. 1923.
- (3) GREENE, WESLEY. Growing tomatoes under glass. The Fruit Belt, 1: 28.
- (4) IGGULDEN, W. Tomatoes. London Agr. & Hort. Assoc. Ltd., 1908, p. 14.
- (5) PRITCHARD, FRED J., AND PORTE, W. S. Effect of fertilizers and lime on control of tomato leaf spot (*Septoria lycopersici*). Phytopath. 11: 433-445. 1921.
- (6) WATTS, RALPH L. Vegetable gardening, p. 452.

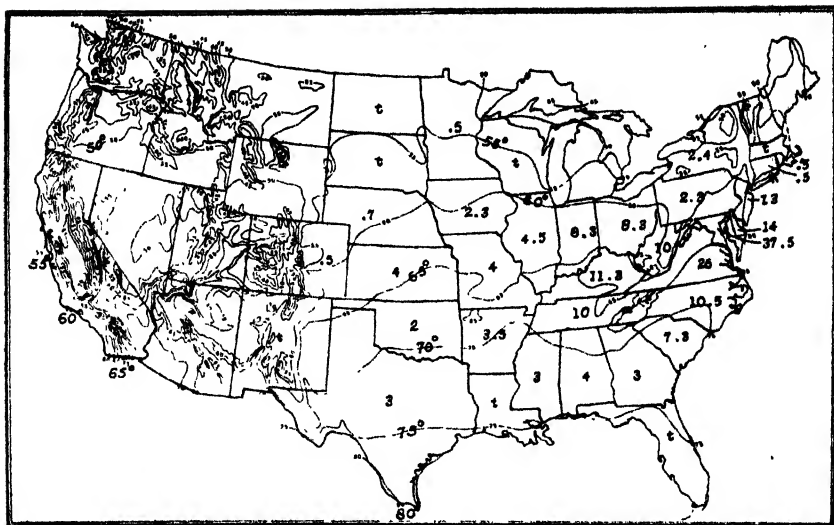


FIG. 2. Average monthly temperature for May and percentage of tomato crop destroyed by leaf spot (*Septoria lycopersici*) from 1918 to 1921.

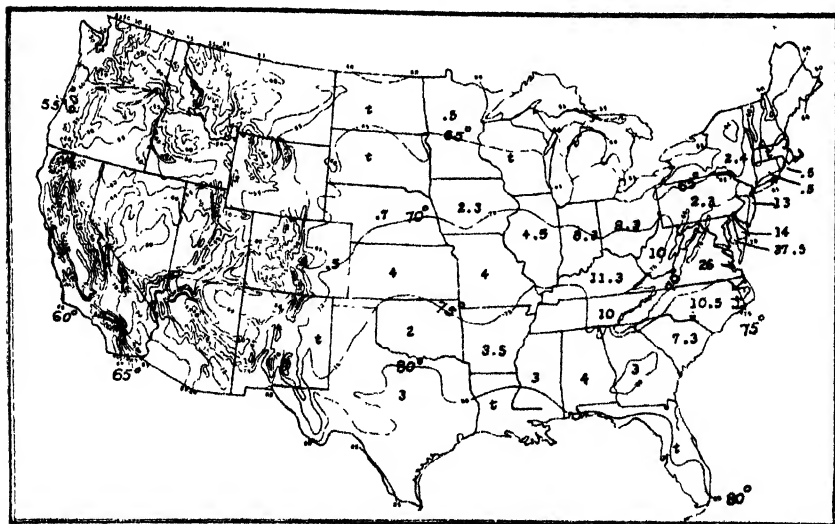


FIG. 3. Average monthly temperature for June and percentage of tomato crop destroyed by leaf spot (*Septoria lycopersici*) from 1918 to 1921.

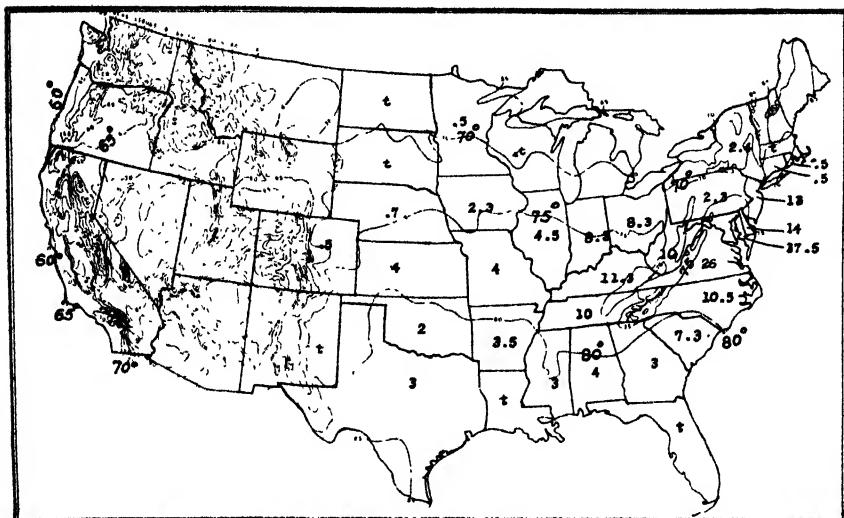


FIG. 4. Average monthly temperature for July and percentage of tomato crop destroyed by leaf spot (*Septoria lycopersici*) from 1918 to 1921.

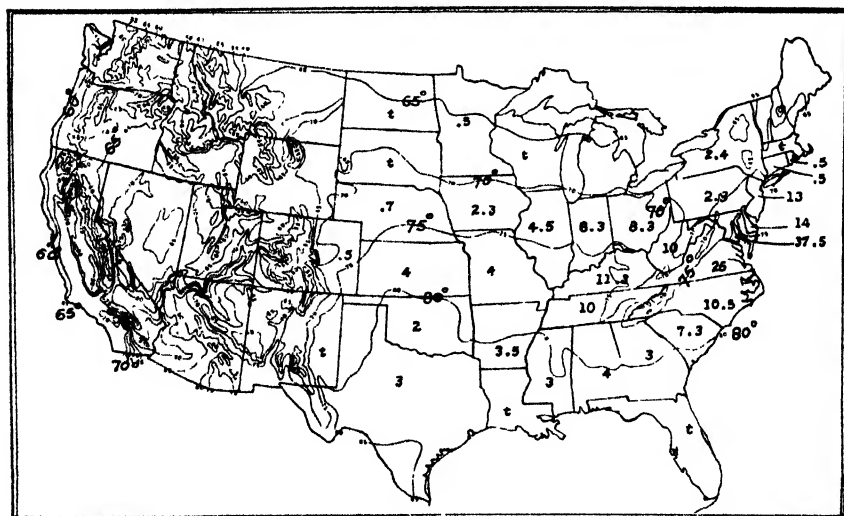


FIG. 5. Average monthly temperature for August and percentage of tomato crop destroyed by leaf spot (*Septoria lycopersici*) from 1918 to 1921.

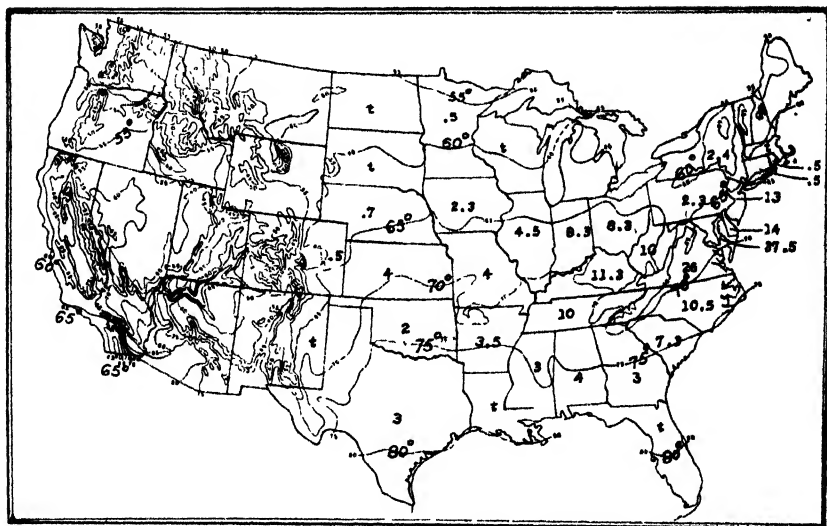


FIG. 6. Average monthly temperature for September and percentage of tomato crop destroyed by leaf spot (*Septoria lycopersici*) from 1918 to 1921.

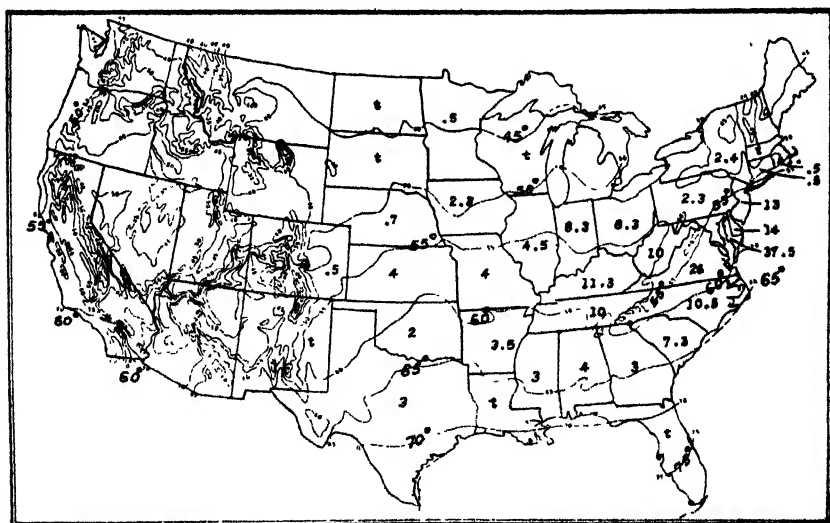


FIG. 7. Average monthly temperature for October and percentage of tomato crop destroyed by leaf spot (*Septoria lycopersici*) from 1918 to 1921.

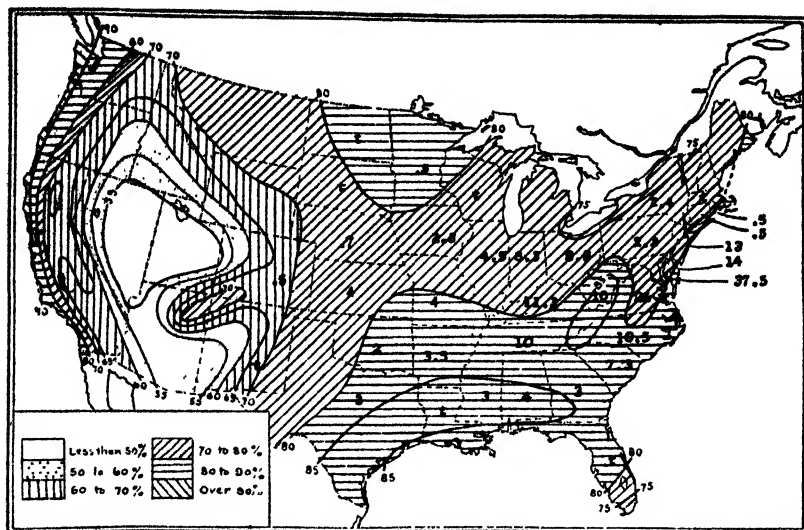


FIG. 8. July average relative humidity, 8 a. m., 75th meridian time, and percentage loss of tomatoes from Septoria leaf spot (1918-1921).

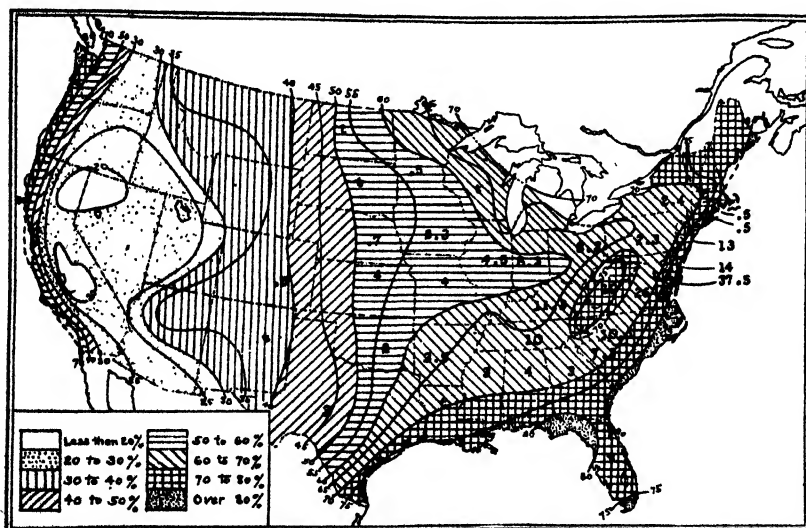


FIG. 9. July average relative humidity, 8 p. m., 75th meridian time, and percentage loss of tomatoes from Septoria leaf spot (1918-1921).

GRAPE RUST IN FLORIDA

C. L. SHEAR

Owing to the great interest recently shown in grape culture in Florida any information in regard to the occurrence, relative importance and, control of diseases, should be useful, especially in view of the fact that, according to the writer's observations in the past three years, fungus diseases are one of the chief factors in determining the commercial success of grape-growing in that State. Anthracnose, black rot and mildew have heretofore been regarded as the most serious diseases to be contended with in this region. Observations made by the writer on about thirty varieties of grapes being grown in the vicinity of Orlando, Florida, show that there is another disease which is perhaps more serious under some conditions than any of those already mentioned. We refer to the grape rust, *Physopella vitis* of Arthur in the North American Flora, (*Phakospora vitis* (Thüm.) Syd.) at least so far as the Florida material he includes under his name is concerned.

This is probably the same rust referred to by Burger in the Annual Report of the Florida Agricultural Experiment Station, for 1922, as found at one place in Florida. "The infection was slight but the different varieties showed differences in susceptibility." Dr. Weber of the same station in a report to the Plant Disease Survey mentions finding the rust at several places in South Central Florida. How long it has been present there on cultivated grapes is not known.

A discussion of the identity, synonymy and distribution of this rust would make an interesting chapter alone. We have not the necessary information, however, at present to settle these questions, therefore, we must leave them until a later time and a more appropriate place. Arthur gives the distribution of this rust as Florida, South Carolina, Cuba and Japan. Sydow also reports it from Jamaica in addition to the localities given by Arthur. The oldest name, *Uredo vitis* Thüm., was based on material collected by Ravenel on *Vitis vinifera* at Aiken, South Carolina. Viala, however, states that he has examined Thümen's and Ravenel's specimens and finds that they bear no rust whatever; but show simply some abnormal conditions of the host cells giving these cells somewhat the appearance of rust spores. Suffice it to say here that, whatever the original name or synonymy of this fungus may be, it is fairly well covered by Arthur's descriptions, so far as the *Uredo* stage is concerned, and this thus far is the only stage we have found on either

the wild or cultivated grape in Florida.¹ This rust is very common on the wild grape, *Vitis munsoniana*, from Orlando south, and has been collected and observed by the writer in many localities in Florida where this grape occurs. As to its northern distribution, we cannot say, except that we have not yet observed it on *Vitis rotundifolia* anywhere in North Carolina, South Carolina, or Georgia.

What appears to be this same rust was found in abundance on practically all of the varieties grown in the Orlando vineyards. At the time of our visit, November 10, 1923, most of the varieties had been almost completely defoliated by the rust, and we were informed by the superintendent of the vineyard that defoliation began three or four weeks previous. Judging from the very small amount of vine-growths made by most of the defoliated plants, the injury must have commenced much earlier in the season. Most of the vines had produced only short shoots with short nodes, which were certainly not capable of producing a profitable crop of grapes next season. A few of the varieties showed considerable resistance to the rust, or at least were able to hold their foliage and to make a rather satisfactory growth of bearing wood for another season. Among these were the varieties Fern, Blondin, Wonder, Royal, and Carmen. The latter variety seemed best able to withstand the attack of the rust of any of the varieties observed. This is very fortunate, as the Carmen has proven one of the most successful varieties at present grown in Florida. Judging from the effect of one or two seasons' injury by rust, most of the varieties would soon be so dwarfed and stunted as to produce little or no fruit. Since spraying for the control of rust has never been a practical success in other cases, there is little hope for any great benefit in this case. Of the other diseases mentioned, anthracnose is apparently the most serious at Orlando. While this disease can be satisfactorily controlled by pruning, dormant treatment with lime sulphur and three or four applications of Bordeaux during the growing season, the conditions of development of the vines in Florida make it necessary to make a much greater number of applications of fungicide to secure results, as there is no uniformity of development of different vines. Individual vines start growing at different times and this condition, combined with the great length of season, makes successful spraying very laborious and expensive.

BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

¹Since this was written specimens showing telia and teliospores associated with the uredinia have been received from Florida.

RECOMMENDATIONS FOR THE IMPROVEMENT OF OFFICIAL INSPECTION FOR CROWN-GALL

F. C. STEWART

During the past year a committee consisting of two plant pathologists, representing the American Phytopathological Society; a horticulturist, representing the American Society for Horticultural Science; a nursery inspector, representing the American Association of Economic Entomologists; and a nurseryman, representing the American Association of Nurserymen, have made a study of crown-gall and crown-gall inspection with a view to the formulation of recommendations for the improvement of present methods of official inspection of nursery stock for crown-gall.

Following the crown-gall symposium at the recent Cincinnati meeting of the American Phytopathological Society this committee submitted the following report which was formally adopted by the Society at its business meeting on December 31, 1923:

REPORT OF COMMITTEE ON CROWN-GALL INSPECTION

1. Owing to the wide distribution of *Bacterium tumefaciens*, the large number of its host plants, and the difficulty of detecting all affected plants, official inspection of nursery stock for the purpose of preventing the dissemination of the crown-gall organism is unwarranted. The sole object of crown-gall inspection is to prevent the sale and planting of stock which will not produce a normal crop. If it be assumed that all plants affected by crown-gall are unfit for planting no method of official inspection is adequate protection for the planter, because of the nature and wide distribution of the causal agent. Inspection regulations should be framed with these things in mind and a clear distinction should be made between crown-gall and malformations due to excessive callousing, cultivation injury, woolly aphis, and nematode injury.

2. The amount of injury done by crown-gall varies greatly with different species of plants and, in some cases, even with different varieties of the same species. Also, it appears to vary somewhat with the character of the soil, methods of culture, and climatic conditions. Accordingly, it is impracticable to have uniform inspection regulations for all kinds of plants or for all parts of the United States.

3. In each state the extent of the injury done by crown-gall to the principal economic plants grown in the state should be accurately deter-

mined and the findings used as the basis of inspection regulations. Generally speaking, the persons best qualified to do this are the plant pathologists and horticulturists of the Agricultural College and the Agricultural Experiment Station. They should be consulted freely by those in charge of nursery inspection.

4. In general, the injurious effects of crown-gall have been over estimated, particularly in the case of the apple. Crown-gall injury is least pronounced in the northern and northeastern portions of the United States.

5. Crown-gall inspection regulations should describe fully, and as accurately as may be possible, the symptoms shown by plants to be rejected. To say that "all plants visibly affected by crown-gall will be rejected" is not sufficiently explicit. Hair-splitting methods of inspection are unnecessary and should not be permitted. Considerable tolerance should be allowed.

6. Field inspection for crown-gall is unreliable. The only worth-while inspection is that made at the packing shed or at the point of destination.

7. Except as a penalty for law violation, the rejection of an entire shipment because some plants in it are affected by crown-gall is unwarranted.

8. In view of the foregoing it is recommended that this Society solicit the active cooperation of the American Association of Nurserymen in a research program that will ultimately answer the questions now involved, directly and indirectly, in a better understanding of the nursery inspection problems relating to crown-gall.

Respectfully submitted,

F. C. Stewart

I. E. Melhus

M. J. Dorsey

H. F. Dietz

H. B. Chase

Committee.

On January 1, 1924, the above report was adopted by the American Association of Economic Entomologists meeting in Cincinnati, Ohio.

It is hoped that the principles enunciated in the report of the committee may be so applied by those in charge of nursery inspection as to bring about inspection methods and regulations more rational than those now in vogue.

The February number of Phytopathology was issued March 20, 1924.

PHYTOPATHOLOGY

VOLUME XIV

APRIL, 1924

NUMBER 4

HOST PLANTS OF *BACTERIUM TABACUM*

JAMES JOHNSON, C. M. SLAGG AND H. F. MURWIN¹

WITH PLATES V AND VI

One of the most promising methods for the control of the wildfire disease of tobacco caused by *Bacterium tabacum* Wolf and Foster, seems to lie in the prevention of seed bed infestation. This involves problems of over-wintering, upon which investigations are in progress in this laboratory. In this connection we were led to investigate other probable host plants of the wildfire organism, since it is conceivable that infested material may enter the seed bed from such sources, either through actual over-wintering in perennials or through dried infected materials being transferred to the seed beds.

The results of the study of the possible host plants of the wildfire organism are believed to be of sufficient interest to warrant publication. We are not prepared to say, however, that any of the plants which we have found susceptible to attack by *B. tabacum* are of practical importance in relation to over-wintering and control of the disease in question.

EARLIER OBSERVATIONS

Wolf and Foster (3) first described the wildfire disease of tobacco, and at that time reported apparent infection on cow-peas, but that infection was not secured on pepper and jimson weed in their trials. Wolf and Moss (4) later reported unsuccessful attempts to inoculate the Irish potato, tomato, pepper, egg plant, jimson weed, and horse nettle. Similar results were reported by Clinton and McCormick (2) on tomato, jimson weed, poke-weed, pepper and egg plants, although in the case of the two latter plants the results of inoculations were doubtful.

Chapman and Anderson (1), however, secured infection on petunia, egg plant and poke-weed, and report finding wildfire on tomato plants growing in an infected tobacco seed bed.

¹ Wisconsin Agricultural Experiment Station in cooperation with the Bureau of Plant Industry, United States Department of Agriculture. Published with the permission of the Director of the Wisconsin Experiment Station.

EXPERIMENTAL METHODS

Our early experience with the wildfire organism indicated that at times our cultures of *B. tabacum* lost all or part of their pathogenicity, in some cases in a comparatively short period. In our inoculation work, therefore, we made certain that a good pathogenic culture was used as judged by the virulence of attack on tobacco plants inoculated at the same time.

The plants inoculated were usually grown in pots in the greenhouse, and were in most cases transferred to a damp chamber for one to two days after inoculation. Some judgment was used in making the inoculations at a stage of growth when the foliage seemed most likely to be susceptible. This was usually during a rapid stage of growth or before the plants were in any way stunted by unfavorable conditions.

Wildfire inoculations without wounding are always less likely to give infection than when wounds are present. With a good culture and reasonably favorable environmental conditions, however, excellent infection may often be obtained without wounding. In the host plant study we have used both methods. Positive results were more often secured by inoculation with needle punctures on which a droplet of water suspension of the wildfire organism was used. We interpret infection secured by this means as an indication of parasitism, recognizing that the degree of susceptibility may be considerably less, however, than where infection can be readily secured without wounding the epidermis.

In cases where infections appeared questionable on first trial, the inoculations were usually repeated. Duplicate sets of inoculations were always made and usually fifty or more wounds were produced in each case.

EXPERIMENTAL RESULTS

The details of the data concerning the extent of infection or relative susceptibility of the hosts, and the type of lesions produced in the wound and atomizer inoculations do not seem to be of sufficient importance to warrant publication at this time. It is deemed sufficient, therefore, to merely list the plants which we have found susceptible to attack by the wildfire organism. We have for the most part grouped these in the botanical families or genera to which they belong. If symptoms of the disease occurred with wound inoculations, even though comparatively slight, the plants are included in the list. Although infection was secured, in most cases, without wounding, failure to secure it in this manner was not regarded as sufficient cause for removal of the plants concerned from the host list, established by the wound inoculations.

SOLANACEAE. It was hoped that some of the various species or distinct varieties of *Nicotiana*, to which tobacco belongs, might prove immune to attack by the wildfire organism, and possibly form the basis for the breeding of a resistant commercial type, since there has been no evidence that any of the ordinary varieties of *N. tabacum* show resistant qualities. All of the species and varieties tested, however, proved to be quite uniformly susceptible to wound inoculations, although fairly marked differences occurred when the organism was applied by the atomizer only. Further study would be necessary, however, to establish any actual variation in this respect.

The following species were infected: *N. glauca*, *N. rustica*, *N. acuminata*, *N. Bigelovei*, *N. suaveolens*, *N. repanda*, *N. paniculata*, *N. alata grandiflora*, *N. sylvestris*, *N. langsдорffii*, *N. glutinosa*. In addition the following types probably most correctly classed as varieties of *N. tabacum* were infected: *angustifolia*, *atropurpureum*, *calyciflora*, *laterrima*, *macrophylla*, *chinensis*, *trigonophylla*, *campanulata*.

Infection was also secured upon pepper (*Capsicum annuum*), egg plant (*Solanum melongena*), tomato (*Lycopersicum esculentum*), potato (*Solanum tuberosum*), ground cherry (*Physalis grandiflora*), black nightshade (*Solanum nigrum*) and jimson weed (*Datura stramonium*).

While good infection could be secured on all these plants with or without wounding, this family is not on the whole apparently any more susceptible to the wildfire organism than are certain other families. The pepper and egg plant were especially susceptible. As a genus, however, it is believed that the *Nicotianas* are more likely to become attacked than are any other plants in this or other families.

CUCURBITACEAE. Heavy infection was secured upon muskmelon, (*Cucumis melo*), watermelon (*Citrullus vulgaris*), pumpkin (*Cucurbita pepo*) and cucumber (*Cucumis sativa*). No other species of this family were tried.

This family appears to be especially susceptible to attack, however, probably ranking with the Solanaceous family in this respect. The watermelon and muskmelon plants were practically killed by the wildfire disease, both in the wounded and unwounded series.

LEGUMINOSEAE. Infection was secured upon bean (*Phaseolus vulgaris*), garden and field pea (*Pisum sativum*), peanut (*Arachis hypogaea*), soy bean (*Glycine hispida*), vetch (*Vicia villosa*), cowpea (*Vigna sinensis*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), alsike clover (*Trifolium hybridum*), alfalfa (*Medicago sativa*). Biennial white blossom sweet clover (*Melilotus alba*), biennial yellow blossom sweet

clover (*Melilotus officinalis*) and Hubam or annual sweet clover (*Melilotus sp.*). No particularly marked susceptibility was noted in this group of plants, although most of them could be infected without wounding the tissues. The bean and peanut produced particularly typical symptoms of wildfire.

GRAMINEAE. Infection was secured upon the following species: wheat (*Triticum sativum*), barley (*Hordeum vulgare*), rye (*Secale cereale*), corn (*Zea mays*), oats (*Avena sativa*), timothy (*Phleum pratense*), quack grass (*Agropyrum repens*), witch grass (*Panicum capillare*), orchard grass (*Dactylis glomerata*), sudan grass (*Andropogon sorghum*) and yellow foxtail (*Setaria glauca*).

The susceptibility of this family of plants appears to be relatively low. Typical halos were secured by wound inoculations and considerable infection from atomizer inoculations, but on the whole the infections were not abundant enough to endanger the plants.

CRUCIFERAE. The following representatives of this family were infected: cabbage (*Brassica oleracea*), turnip (*Brassica rapa*), rutabaga (*Brassica campestris*), radish (*Raphanus sativus*), rape (*Brassica napus*), mustard (*Brassica alba*) and Shepards purse (*Capsella Bursa-pastoris*).

These plants proved quite susceptible on the whole, mustard, for instance, becoming heavily infected from atomizer inoculation. On the others typical and large halos were usually produced by wound inoculation. This group appears more susceptible than the grass family, and probably ranks with the legumes in this respect.

COMPOSITAE. Eight species from this family were inoculated and of these six became infected. These were: sunflower (*Helianthus annuus*), dandelion (*Taraxacum officinale*), ragweed (*Ambrosia artemisiifolia*), sow thistle (*Sonchus oleraceus*), Canada thistle (*Cirsium arvense*) and prickly lettuce (*Lactuca scariola*). Garden lettuce (*Lactuca sativa*) and cineraria (*Senecio cruentus*) could not be infected in our trials.

With the exception of the Canada thistle the plants listed as infected proved to be quite susceptible to both wound and atomizer inoculations.

POLYGONACEAE. Six species were inoculated and infection was secured upon five, namely: Buckwheat (*Fagopyrum esculentum*), ladies-thumb (*Polygonum persicaria*), bind-weed (*Polygonum convolvulus*), knot-weed (*Polygonum erectum*) and red dock (*Rumex acetosella*).

Infection was not secured upon curled dock (*Rumex crispus*). Buckwheat and ladies-thumb were quite susceptible, especially to wound inoculations, but red dock only slightly so.

CHENOPODIACEAE. Both the garden and sugar beet (*Beta vulgaris*)

were infected, as was spinach (*Spinacea oleracea*) and lambs-quarter (*Chenopodium album*).

MALVACEAE. Cotton (*Gossypium herbaceum*) and mallow (*Malva rotundifolia*) gave good infection both on wounded and unwounded foliage.

LABIATAE. Three representatives of this family were inoculated and infected, namely: catnip (*Nepeta cataria*), coleus (*Coleus blumei*) and salvia (*Salvia splendens*). The infection was marked on catnip only.

UMBELLIFERAE. Carrot (*Daucus carota*) and parsnip (*Pastinaca sativa*) could only be infected with considerable difficulty.

MISCELLANEOUS SPECIES. Infection was also secured on single species from thirteen other families. These are: chickweed (*Stellaria media*), plantain (*Plantago major*), purslane (*Portulaca oleracea*), evening primrose (*Oenothera biennis*), pig-weed (*Amaranthus retroflexus*), poke-weed (*Phytolacca decandra*), tulip (*Tulipa* sp.), barberry (*Berberis vulgaris*), mullein (*Verbascum thapsus*), bryophyllum (*Bryophyllum* sp.), jewel-weed (*Impatiens*), rose (*Rosa* spp.) and maple (seedling) (*Acer saccharinum*).

DISCUSSION OF RESULTS

We have by no means made an attempt to cover the host range of *Bacterium tabacum*. The plants inoculated were selected primarily as representing crop plants or common weeds, which were most likely to be concerned in over-wintering. They represent, therefore, a somewhat random selection from among the botanical families of plants. Fully ninety per cent of the plants with which we worked gave more or less infection upon inoculation. The host list could, therefore, probably be greatly increased by further trials.

No cases of marked outbreak of the wildfire disease on other crops than tobacco have come to our attention. It is not unlikely, however, that such may occur on some crops, judging by our comparative inoculations on tobacco. Natural field infection has been noted to occur on cowpeas by Wolf and Foster (3), on tomato by Chapman and Anderson (1), and on cucumber by one of us.

Our results cannot be accounted for on the basis of using any particular strain of *B. tabacum*. A large number of different strains have been used in our laboratory, and those used were selected practically at random, care being taken only to have vigorously pathogenic strains. Reference to our early notes shows that in October, 1918, we infected *Nicotiana glauca*, *N. rustica*, *Vigna sinensis*, *Secale cereale* and *Cucumis sativa* with a culture of *B. tabacum* secured from Wolf.

The ability of *B. tabacum* to attack such a wide range of plants seems to indicate unusual adaptation on the part of the parasite. On the other hand, it is believed that many of our plant parasites would behave in a more or less similar way when submitted to trial. The gradual adaptation of parasites to their hosts, and the outbreak of "new" diseases seems to be well illustrated in such studies. If wildfire is really a "new" disease of tobacco it is not difficult to believe that the parasite may have previously existed on some other host from which it has recently passed to the tobacco.

SUMMARY

1. *Bacterium tabacum* Wolf and Foster, the causal organism of the wildfire disease of tobacco, is capable of producing disease symptoms, more or less typical, on a wide variety of plants.

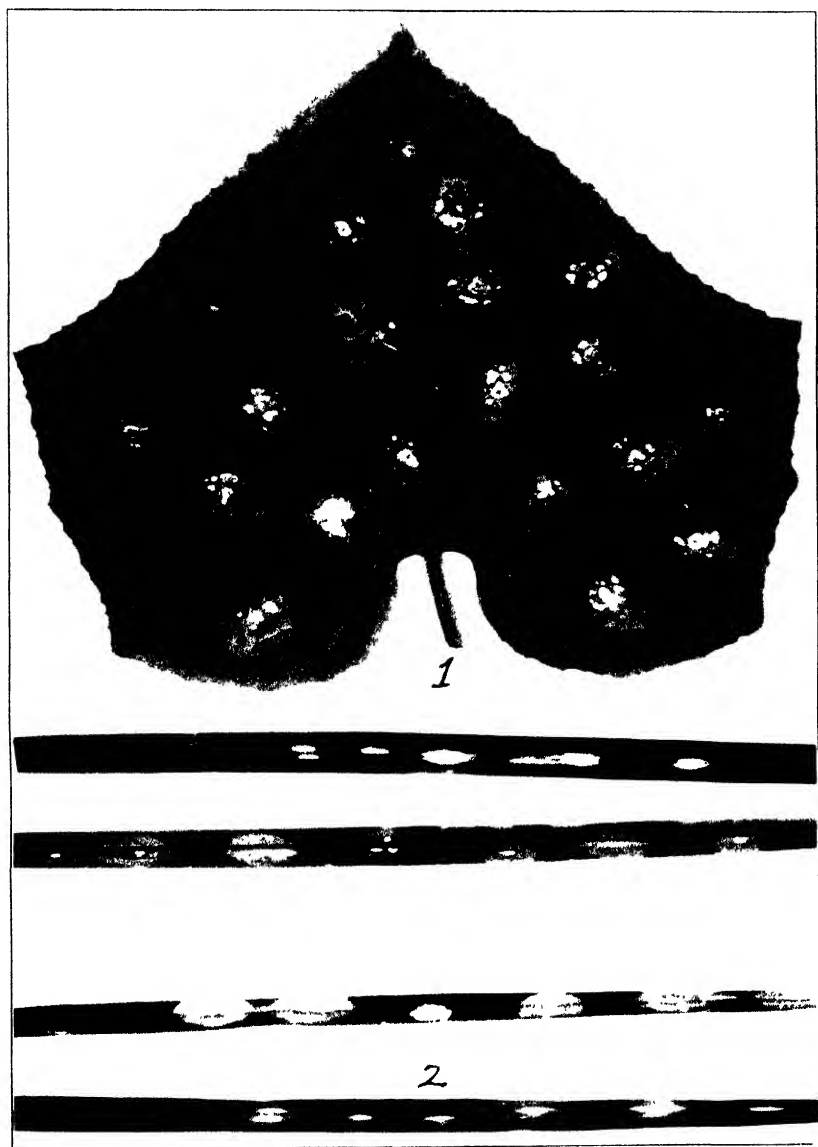
2. Infection has been secured upon twelve species of *Nicotiana* and seven other members of the Solanaceae. Four species of the Cucurbitaceae, thirteen of Leguminosae, eleven of the Gramineae, seven of the Cruciferae, six of the Compositae, five of the Polygonaceae, three of the Chenopodiaceae, three of the Labiatae, two of the Malvaceae, two of the Umbelliferae and single species of thirteen other families have been shown to be susceptible to attack.

3. The large majority of the plants inoculated were infected, and it is therefore believed that the host range of *B. tabacum* is very much larger than indicated by these results.

4. The inoculations were undertaken primarily to study possible sources of the overwintering of the wildfire organism. The results are published separately for the general interest they may have, and their probable bearing on theories of parasitic adaptation and the origin of disease.

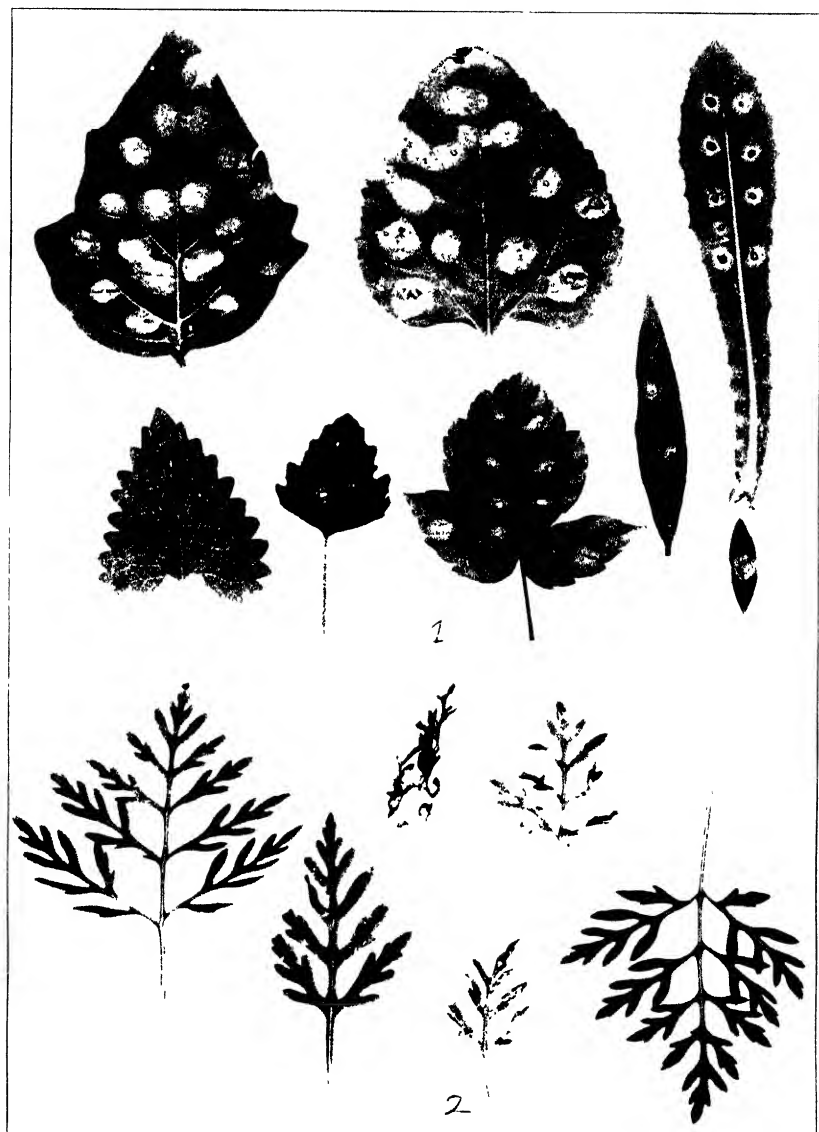
LITERATURE CITED

- (1) CHAPMAN, G. H., AND P. J. ANDERSON. Tobacco wildfire. Preliminary report of investigations. Massachusetts Agric. Exp. Sta. Bull. 203: 67-81. Pl. 1. 1921. Literature cited, p. 81.
- (2) CLINTON, G. P., AND F. A. MCCORMICK. Wildfire of tobacco in Connecticut. Connecticut Agric. Exp. Sta. Bull. 239: 365-423. Pls. 19-22. 1922. Literature cited, p. 422-423.
- (3) WOLF, F. A., AND A. C. FOSTER. Tobacco wildfire. Jour. Agric. Res. 12: 449-458. Pl. 15-16. 1918.
- (4) WOLF, F. A., AND E. G. MOSS. Diseases of flue-cured tobacco with suggestions for application of palliative, preventive and remedial measures. The Bull. North Carolina Dept. Agric. 40: 5-45. 1919. References, p. 44.



BACTERIUM TABACUM ON VARIOUS HOSTS.

FIG. 1. Cucumber leaf showing typical "wildfire" (*Bacterium tabacum*) infection following wound inoculations. FIG. 2. Leaf blades of timothy and quack grass showing halos produced following wound inoculations with *B. tabacum*.



BACTERIUM TABACUM ON VARIOUS HOSTS

FIG. 1. Leaves of poke-weed, sunflower, prickly lettuce, catnip, lambs-quarter, maple, ladies-thumb, and chick-weed infected with the wildfire organism by wound inoculations. FIG. 2. Stages of the wildfire disease on common ragweed following inoculation by atomizing suspension of organism on unwounded plant. Inverted leaf from control plant.

TOBACCO WILDFIRE AND TOBACCO SEED TREATMENT

H. E. THOMAS

WITH ONE FIGURE IN THE TEXT

Wildfire of tobacco was first recognized in New York State in July, 1922, on material from Chemung County. The disease had apparently been present in that county for at least one year previous to that date. The results of a limited number of field inspections have indicated that the disease is not as yet widely distributed in the state. Experience during the season of 1922 however left no doubt as to the severity of the disease where it has become established. This paper records some observations and experiments relating to the overwintering of *Bacterium tabacum* (Wolf and Foster) and more particularly to the treatment and handling of tobacco seed.

OVERWINTERING OF BACTERIUM TABACUM

A wide difference of opinion prevails in regard to the manner of overwintering of *Bacterium tabacum* (1), (2), (3), (5). In this connection an interesting observation was made in 1923 with reference to the seed as a carrier of the pathogene. A grower planted part of a bed with seed treated in corrosive sublimate and the remainder of the same bed with untreated seed. The bed was examined by the writer just before transplanting time and the plants from untreated seed were quite generally infected. In contrast no wildfire could be found on any of the plants from treated seed, except those adjacent to the junction line.

In the study of the overwintering of the organism in the field only one experiment, Clinton and McCormick (2), seems to have yielded positive evidence. The observations of Fromme and Wingard (3) and Anderson and Chapman (1) suggest that overwintering in the field is possible. The following experiment is of interest in this relation. On April 12, 1923, about 4 bushels of tobacco stems, roots and leaves were collected in a field which had grown a badly diseased crop in 1922. On April 19 this material was buried 1 to 3 inches deep in 4 trenches each 30 ft. long on the College Farm at Ithaca. Plants were started in the greenhouse on steamed soil from seed treated in corrosive sublimate. One plot (no. 1) was planted in rows directly over the buried stems on June 8. Plants from the same lot were set in a control plot (no. 2) about 350 feet distant in the same field. No wildfire could be found on the

transplants and no other tobacco fields were known within 20 miles of Ithaca. The midsummer season was unusually dry and frequent inspections failed to discover symptoms of wildfire in either plot until September 18 when 1 plant in plot 1 showed a few spots typical of wildfire. On September 25, 2 additional plants in the opposite end of the plot showed similar symptoms and by October 2, 13 of the 50 plants in this plot showed light to severe infection. Up to this last observation, no wildfire could be seen in plot 2.

SEED TREATMENT AND SEED GERMINATION

In the spring of 1923 a number of New York tobacco growers used for the first time the standard method of seed treatment,—mercuric chloride 1:1000 for 12 to 15 minutes. Most of these growers reported difficulty in germinating the treated seed and some failed to obtain any germination. The failure was too general to be attributed to faulty handling of the seed treatment. An inquiry brought out that these growers regularly practice germinating the seed in bulk in moist rotten wood, a woolen cloth or a discarded sock before it is sown upon the bed. This practice is believed to be necessary on account of the shortness of the growing season. In the warmer states where seed treatment has been used with excellent results, the seed is sown directly on the bed without previous germination.

Anderson and Chapman (1) report from Massachusetts a condition somewhat similar to that in New York State as regards the failure of germination in bulk of treated seed.¹ These authors believe that the failure to germinate is due to hardening of the seed coat after drying rather than to the chemical which is used in treatment. They obtained better germination of treated seed in bulk at relatively low temperatures and high moisture content.

The writer made several experiments in 1923 bearing on the various methods of seed treatment and germination. The seed used in these tests was of the Connecticut Havana Type and mostly of the 1922 crop. When mercuric chloride was used, unless otherwise stated, the treatment was for 15 minutes in a 1-1000 solution and the seed was washed for 10-20 minutes in tap water and dried before germinating. Aside from sowing on the soil two methods of germination were used corresponding to that used in developing the seed treatment method (4) and to the method of

¹ Since this was written the abstract of Johnson and Murwin has appeared in *Phytopathology* for January, 1924.

handling employed by our growers. In the former the seed was sown thinly on filter paper placed on moist sand in a glass dish, usually a petri dish. In the latter method the seed was tied in muslin or cheesecloth bags in lots of 5 to 20 grams and placed in an open dish with sufficient cloth or moist sand to maintain a desired water content.

In an early test it was found that treated seed (6 years old) germinated above 90 per cent when sown on soil in the greenhouse while a sample from the same lot wrapped in cheesecloth and placed in a moist chamber at 26° C. showed no germination.

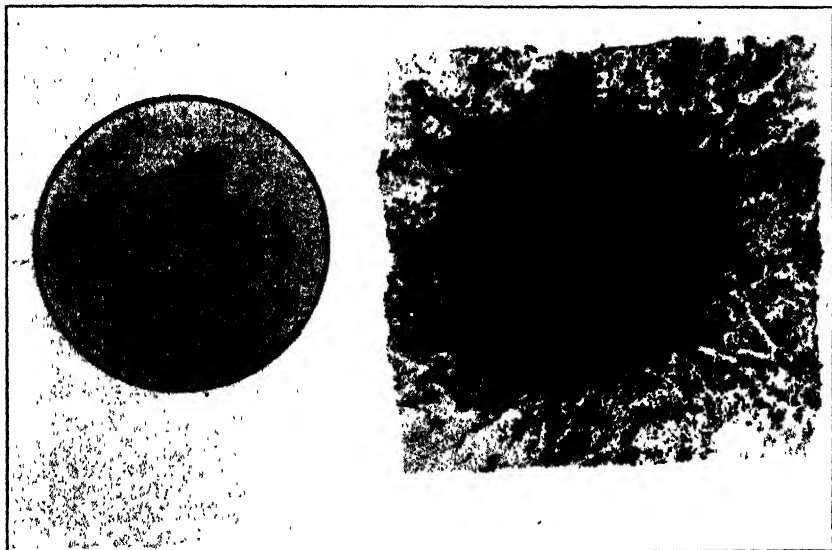


FIG. 1. Tobacco seed treated in mercuric chloride. Germination in muslin bag and on filter paper in petri dish

More extensive tests were then made with both treated and untreated seed using the two methods of germination described above. The results may be summarized as follows: In the glass dishes, 10 samples from 4 different corrosive sublimate treatments averaged 90.6 (82-97) per cent germination while 5 comparable untreated samples averaged 93.8 (89-98) per cent germination. There was in some cases a noticeable slowing in the rate of germination of the treated seed. This was apparently responsible for part at least of the slight differences noted above. In striking contrast were the results of attempts to germinate treated and

untreated seed in bulk (figure 1). Five lots of seed treated in mercuric chloride gave no germination whatever. Even when one lot was spread in a large moist chamber in a layer about 1 centimeter deep there was still no sign of germination. The germination of untreated seed in cloth bags was very irregular. Due to the fact that the rate and percentage of germination was much higher in the exterior part of the mass, it was impossible to obtain counts representative of the entire lot. Three such tests gave maximum counts of 57, 61 and 64 per cent. A count from the interior of the last lot, however, showed only 10 per cent of germination. One lot at 33° C. and another at 26° C. with excessive watering gave no germination.

As evidence that the failure of germination in bulk following the mercuric chloride treatment is probably due to the direct action of the chemical, it may be noted that seed treated in the following ways germinated very much as did untreated seed both in bulk and in petri dishes: copper sulfate, 2 per cent and 5 per cent solutions for 20 minutes followed by washing in lime water; potassium dichromate, 10 per cent for 10 minutes; potassium permanganate, 5 per cent for 20 minutes; sulfuric acid, 10 per cent for 5 minutes. Germination was especially good following the copper sulfate treatment. However in the concentrations used this material did not seem to entirely inhibit the bacteria on seed which had previously been soaked in a suspension of the wildfire organism.

Since formaldehyde treatment had already been discarded by some workers for use with tobacco seed on account of possible injury, it was assumed that this material would completely inhibit the germination of seed in bulk. When it was finally resorted to, however, the results were surprising. When seed was treated in formalin 1 to 16 for 15 minutes and washed for 15 minutes in tap water the germination in bulk at 26° C. appeared to the eye to be practically as good as that of the untreated control. Counts from the interior of the mass, however, showed a considerably higher germination in the untreated seed (61 per cent as compared with 29 per cent in the treated lot).

Here again the germination was very much better in both lots next to the cloth on the outside of the mass. In a second trial, seed was treated in a 1 to 16 solution for 10 minutes and washed in running water for 10 minutes. There was evidence of slight injury when this seed was germinated in petri dishes but in bulk there was no significant difference in the percentage of germination as determined by counts from the interior of the mass. The use of this material should be investigated further if the practice of germinating the seed in bulk is to be continued.

When seed was sown on soil in the greenhouse there was strong and uniform germination in that treated in mercuric chloride as well as in untreated seed. This was likewise true of seed treated in copper sulfate solution, 2 per cent for 20 minutes, and sulfuric acid solution, 10 per cent for 5 minutes.

SOME FACTORS INFLUENCING THE GERMINATION OF SEED

In view of the results recorded above and of those described by Anderson and Chapman (1) it seemed desirable to examine some of the factors, other than treatment with chemicals, which might influence the germination of tobacco seed.

Temperature. In an early trial with rather poor seed no germination could be obtained at 33° C. either in glass dishes or in bulk. At 26° C. the same lot gave 51 per cent germination in bulk and as high as 78 per cent in petri dishes. A later test in petri dishes with better seed gave in 4 samples an average of 18.7 per cent germination at 33° C. and 90.2 per cent at 26° C. No controlled temperature was maintained below 26° C. but splendid germination was obtained at laboratory temperatures ranging usually from 21° to 25° C.

These observations indicate a rather sharply defined maximum temperature for the germination of tobacco seed and point to a source of possible loss of seed under the farm practice of germination at extremely variable temperatures.

Moisture. In 2 tests a total of 10 samples were germinated in glass dishes in which the sand received slightly more water than it would take up though not enough to immerse the seed. Seven samples were run in parallel on sand to which was added barely enough water to moisten it. No appreciable difference in percentage of germination resulted. In seed in muslin bags with heavy watering, however, germination was poor or lacking entirely.

Aeration. It has already been noted that seed on the outside of a mass in bulk germinated more readily than those in the interior of the mass. To study this factor further two columns of seed $1\frac{3}{4}$ inches high were placed over water in glass cylinders $1\frac{3}{4}$ inches in diameter. The cylinders were sealed in a series so that moist air could be drawn through one lot of seed while it merely circulated in the space above the other lot. Germination was about equal in the two lots extending practically to the bottom of the column. A second test was made with columns of seed 6 inches in height. After 11 days there was good germination to within $\frac{1}{2}$ inch of the bottom in the column which received better

aeration, while in the corresponding cylinder germination was practically inhibited beyond $3\frac{1}{2}$ inches from the top of the column.

Drying. Treated seed which was dried in direct sunlight germinated as well as seed dried slowly in the laboratory and in a few cases somewhat better than seed which was not dried after treatment. Seed which was soaked in water and dried without treatment was not perceptibly changed in its power of germination. This is not in agreement with the results obtained by Anderson and Chapman (1).

Age of seed. Seed up to 6 years old has shown good germination under favorable conditions. One lot of seed 5 years old consistently gave above 60 per cent germination.

Rate of development of seedlings from germinated and dry seed. In order to compare the growth of seedlings from seed germinated previous to sowing with that of plants from dry seed, 2 greenhouse beds of equal size (8.5 sq. ft.), were sown with equal quantities of seed by weight, the first germinated and the second dry. Seedlings in the first bed were distinctly in advance of those in the second for several weeks but by the time the plants had reached a size suitable for transplanting the difference between the two beds was not marked. The plants from these beds were pulled after 52 days and weighed immediately. The weight for the first bed was 3332 grams and for the second 2990 grams. While these weights seemed to represent the conditions of the beds fairly well the presence of damping-off in the beds sets in doubt the value of the figures. A third bed to which a fungicide was applied in addition to formaldehyde treatment received by the first and second beds, produced a green weight of 3502 grams from a sowing of dry seed. The above test was repeated in duplicate with similar results as regards the appearance of the plants up to 38 days, after which the experiment was discontinued.

DISCUSSION OF SEED TREATMENT

In the light of the results and observations recorded above it seems fairly certain that tobacco seed, treated by the usual corrosive sublimate method and germinated in bulk, retains a sufficient quantity of the chemical in the seed coat to seriously interfere with the germination of the seed. The results show that the germination of such treated seed is only slightly if at all impaired when it is sown on greenhouse soil or on moist filter paper on sand in the laboratory. It is apparent further that the method of germination in bulk may expose the seed to other hazards that are avoided by sowing the seed directly on the plant bed without

sprouting. Poor aeration and high temperatures are especially likely to hinder germination. When seed previously germinated is sown side by side with dry seed on greenhouse beds, the difference in rate of development of the seedlings is not marked. Indeed after several weeks it is scarcely perceptible. While seed treated in various chemicals other than mercuric chloride has germinated as well as untreated seed under both the methods employed, none of these can at this time be considered desirable for general use without further investigation.

It seems therefore that the most satisfactory method of handling seed for the control of wildfire under New York conditions consists in treatment with corrosive sublimate and sowing the seed directly on the plant bed without previous germination.

SUMMARY

Tobacco seed treated in mercuric chloride 1 to 1000 germinated nearly or quite as well on soil and in thin sowings in moist chambers as did untreated seed. When seed from the same treated lots was held in bulk in muslin or cheesecloth bags no germination was obtained at 26° C. or at 33° C.

Untreated seed in bulk did not germinate as well as did samples from the same lots germinated in petri dishes.

Seed treated in copper sulfate, potassium permanganate, potassium dichromate, and sulfuric acid did not show appreciable injury in the concentrations tested.

Treated and untreated seed germinated well in petri dishes at 26° C. and below. At 33° C. poor germination was obtained.

Drying of wetted seed rapidly in direct sunlight or slowly in the laboratory did not impair germination in these experiments.

LITERATURE CITED

- (1) ANDERSON, P. J., AND G. H. CHAPMAN. Tobacco wildfire in 1922. Mass. Agr. Exp. Sta. Bul. 213: 1-27. 1923.
- (2) CLINTON, G. P., AND FLORENCE A. MCCORMICK. Wildfire of tobacco in Connecticut. Conn. (New Haven) Agr. Exp. Sta. Bul. 239: 365-423. 1922.
- (3) FROMME, F. D., AND S. A. WINGARD. Blackfire and wildfire of tobacco and their control. Va. Agr. Exp. Sta. Bul. 228: 1-19. 1922.
- (4) ———. Blackfire or angular leaf-spot of tobacco. Va. Agric. Exp. Sta. Tech. Bul. 25: 1-43. 2 pl., 18 fig. 1923. Literature cited, p. 42-43.
- (5) WOLF, F. A. Wildfire of tobacco. N. C. Agric. Exp. Sta. Bul. 246: 1-27. 7 figs. 1922. Literature cited, p. 27.

THE BEHAVIOR OF CERTAIN VARIETIES OF TOMATOES TOWARDS FUSARIUM-WILT INFECTION IN CALIFORNIA

MICHAEL SHAPOVALOV AND J. W. LESLEY

WITH PLATES VII AND VIII

Wilt of tomatoes, caused by *Fusarium lycopersici* Sacc., is widely spread in the tomato growing sections of California. In 1922 and 1923 the disease was seen in all the principal tomato sections of the State, notably in those near the coast, such as the Santa Clara and San Fernando Valleys and Orange County. In coastal sections *Fusarium* wilt is more important than western yellow blight. In the interior valleys the relative importance of these two diseases is as a rule reversed; the season of 1923 was probably exceptional in that even in the interior the wilt disease was more prevalent than blight. There has been a great deal of confusion in regard to the relative importance of these two diseases among the general public and the growers, the latter frequently referring to *Fusarium* wilt as "the blight." Undoubtedly wilt causes very serious losses to the tomato industry in California. It is exceptional to find a tomato field entirely free from the disease. Very frequently it destroys from 5 to 10 per cent and sometimes as much as 85 per cent of the crop. In all probability the area of the infected land is steadily increasing as a result of repeated planting of tomatoes in the same field often without rotation.

The work of various Experiment Stations and the United States Department of Agriculture in breeding wilt resistant varieties has been very successful and as a result a number of varieties are now in existence which have proved to be wilt resistant under certain conditions.¹ Notable among these varieties are those developed by Pritchard.² Whether these varieties would maintain their resistance in California was uncertain, owing to the different environmental conditions both climatic and, perhaps, biological under which tomatoes are grown in the State. The purpose of the present investigation is twofold: (1) to study the behavior of wilt resistant varieties from other states when grown under California conditions and (2) to test out selections made in California. It is hoped in this way to find or develop resistant varieties well adapted for local commercial plantings. Seeds for this purpose

¹ The intrinsic resistance of certain tomato varieties to the wilt disease was pointed out by Essary in 1912 (Tenn. Agr. Exp. Sta. Bull. 95, 12 p., 7 figs. 1912).

² Pritchard, Fred. J. U. S. Dept. Agr. Bull. 1015, 18 p., pls. I-X. 1922.

were obtained from seedsmen and experiment stations. These and some selections made by one of us¹ in the summer of 1922 in badly wilted tomato fields in California were subjected to tests in 1923. For convenience these varieties, strains and selections will be referred to here as varieties indiscriminately. As a control Stone was used, a variety widely grown in California and one which is very susceptible to wilt.

Two methods were employed in testing the reaction of varieties, artificial inoculation with a pure culture, following the general procedure described by Edgerton and Moreland² and natural infection obtained by planting in the soil of badly infected fields. For the former method a pure culture of the pathogene is of course necessary and since as noted by Edgerton (l. c.) not all *Fusarium* cultures from wilting plants are pathogenic, two distinct cultures were employed which had been isolated by one of us³ from the diseased plants, collected in California. One of these, designated as F. IV, was isolated from a wilted tomato plant near San Jose, Cal., in July, 1922, and the other, designated as F. V, was isolated in July, 1922, from a wilted plant at Pomona, Cal. The artificial inoculation method was used in an experiment conducted at the Citrus Experiment Station at Riverside on four varieties. Two of these, Stone and Morse's San Jose Canner, are varieties of commercial importance in the State. The third variety, Norton, bred by Pritchard, is also becoming of commercial importance and has proved to be wilt resistant in other parts of the United States and the fourth, No. 23087, is a selection made in 1922 in a badly wilted field of Stone in California.

Twenty four-inch pots with garden soil containing plenty of humus were sterilized at 20 lbs. pressure on three successive days, one hour each day. All pots were covered during the sterilization with heavy wrapping paper and the covers were not removed until the time of planting the seed. Some of the pots were then inoculated with the above mentioned cultures by first removing about two inches of soil from the pot to a disinfected dish, than introducing the contents of a two-week old test-tube culture, grown on string bean pods, after which the soil was replaced. Some pots were not inoculated with either of the two fungi. All the pots were then sown with seed, twenty-eight seed per pot. The seed was disinfected by soaking in 1:400 commercial formaldehyde for one hour, rinsed in distilled water and dried on filter paper before

¹ J. W. Lesley.

² Edgerton, C. W., and Moreland, C. C. La. Agr. Exp. Sta. Bull. 174. 54 p., 19 figs. 1920.

³ Michael Shapovalov.

planting. The pots were placed in saucers and crocks filled to a depth of about $\frac{5}{8}$ inch with water. All dishes and the dibbles used in seed planting were disinfected in 1 per cent commercial formaldehyde. As soon as the plants had developed their first true leaves disease made its appearance in some of the pots, causing the collar or part of the hypocotyl next the soil to shrink and become discolored as in "damping off." On June 8, 1923, about half the seedlings of Stone and San Jose Canner in the pots inoculated with F. V. had died, but only one out of ten plants of the variety 23087 and none of Norton were affected. None of the plants inoculated with F. IV showed disease, indicating that this culture was either less virulent or non-pathogenic. One seedling of Stone uninoculated damped off, presumably owing to accidental infection.

On June 14 all of the San Jose Canner and all but two of Stone inoculated with F. V had died and the remaining inoculated and uninoculated plants were set out in the field. This field had never before been in tomatoes. At the time of planting some plants of each variety from the uninoculated pots were inoculated with F. V by placing a culture in contact with the roots. To serve as controls some plants of each variety were not inoculated either in the pot or in the field. Each variety then consisted of a series of four fractions, pot inoculated with F. V, field inoculated with F. V, pot inoculated with F. IV and uninoculated.

Nearly all the plants set out became established. Four weeks after setting out typical wilt symptoms appeared among the series of varieties inoculated with F. V. The plants inoculated with F. IV, however, showed no symptoms of wilt (except two plants referred to below) behaving in the same way as the uninoculated controls. Differences in the reaction of the four varieties to the culture F. V were again apparent as with the inoculated seedlings when in pots. Nearly all of Stone and San Jose Canner became diseased. Later a few plants of these varieties put up side shoots, but these in turn quickly became infected. On August 3, both of the F. V pot inoculated plants of Stone were dead and of those field inoculated only one plant of Stone and two small plants of San Jose Canner survived, although severely affected. On October 29, the combined yield of these plants was nine immature fruits, two largest being barely of marketable size and the majority smaller than walnuts. In plate VII, the contrast is well shown between that section of a row which had F. V field inoculated plants of San Jose Canner (a) and Stone (b), and another part of the same row planted with uninoculated San Jose Canner (c) and the adjacent row (d) planted with F. IV inoculated plants of several varieties.

Quite different was the reaction of Norton and the Stone selection No. 23087. On August 3, about one-fourth of the F. V pot inoculated plants of these varieties had perished, but the others either appeared unaffected or, if diseased, had begun to make healthy growth. The new growth, unlike that of Stone and San Jose Canner, did not become diseased and ultimately about 75 per cent of the plants of these varieties produced a satisfactory crop, in part quite equal to that of the controls. Forty-four out of forty-six plants inoculated with F. IV showed no *Fusarium* symptoms and only two developed slight signs of wilt. This was probably due to outside infection of the pots in watering or other accidental agency, or, perhaps, to the presence of the fungus in the field.

TABLE 1—*Riverside plot.*

Variety	Treatment	Total number of plants	Apparently healthy	Slightly affected	Medium affected	Severely affected	Died of Fusarium			
							Prior to July 14	From July 14 to Aug. 3	From Aug. 3 to Aug. 29	Total number
Selection 23087 from Stone	Pot inoculated, F. V.	6		3	1		2			2
Norton (from Haven Seed Co.)	" " "	10		7			3			3
Stone (from Haven Seed Co.)	" " "	2					1	1		2
San Jose Canner (from Morse Seed Co.)	" " "	All died in pot								
Selection 23087	Field inoculated, F. V	12		8	1		1	2		3
Norton	" " "	12		10			1	1		2
Stone	" " "	15			1		4	9	1	14
San Jose Canner	" " "	11				2		9		9
Selection 23087	Pot inoculated, F. IV	10	10							
Norton	" " "	9	7	2						
Stone	" " "	20	20							
San Jose Canner	" " "	7	7							
Selection 23087	Uninoculated	13	13							
Norton	" "	12	12							
Stone	" "	11	11							
San Jose Canner	" "	12	12							

These data, summarized in table 1, show clearly that under the growing conditions which obtained in 1923 one of the cultures employed, F. IV, is merely a saprophytic *Fusarium*, while the other, F. V, is a parasite and may cause typical *Fusarium* wilt. The principal cultural and morphological features of F. V correspond very closely to those of *F. lycopersici* a culture of which was obtained from Mr. Pritchard's collection (His No. 103). As to the varietal susceptibility, both Stone

and Morse's San Jose Canner appeared to be very susceptible and about equally so to this pathogene, whereas 23087 and especially Norton showed distinct resistance.

The second method of testing the reaction of varieties, namely natural soil infection, was employed in two fields, one at La Mesa, near San Diego, the other at Chatsworth, in the San Fernando Valley. The La Mesa field had been in tomatoes for the last two seasons, each time 85 per cent of the plants being badly diseased. On this plot four varieties were planted, Norton, Norduke and Marvel, all of which are known elsewhere as wilt resistant, and Stone as a control. All the plants were grown in adjacent seedbeds near Santa Ana, Orange County,¹ and appeared quite healthy when set out on May 15. The Stone plot rapidly developed wilt. On September 9 the majority of the plants were dead, only 5 per cent surviving and these were severely affected. Practically no fruit was obtained from the total of 140 plants. A striking contrast was presented by the adjacent plots of Norton, Norduke and Marvel (Plate VIII). The majority of plants of these varieties were only slightly wilted

TABLE 2—*La Mesa plot.*

Variety	Source	Total number of plants	Slightly affected		Medium affected		Severely affected		Died of Fusarium	
			Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Stone	Haven Seed Co.	140					7	5	133	95
Norton	" " "	47	12	25	24	50	11	25		
Norduke	" " "	55	30	55	22	40	3	5		
Marvel	" " "	13	8	62	5	38				

(Table 2), Norton showing somewhat more disease than Norduke, while Marvel was the least affected. All three varieties made a fairly good crop. Norton although more diseased was superior to both Norduke and Marvel in production. The yield of Norduke plants seemed very variable and the crop matured late in the season. This variety made the best vegetative growth. Marvel gave a good yield of smaller fruit. All of the three, Norton, Norduke and Marvel, are therefore sufficiently wilt resistant to produce a crop which would be considered

¹ Mr. A. B. Haven of the Haven Seed Co., Santa Ana, California, kindly supplied all the seedlings used in this trial and many of the seeds used in the other trials.

satisfactory to a tomato grower whereas under similar field conditions Stone appears so susceptible that it produces no crop.

The other field trial, conducted at Chatsworth, like that at La Mesa was on land so badly infected with the wilt *Fusarium* that the tomato crop of the previous year was practically a total failure. Part of the seeds in this trial were sown in a seedbed containing an admixture of infected soil from this field. Many of the resulting seedlings showed symptoms similar to those seen in the artificially inoculated pots at Riverside indicating an early infection. A considerable number of plants from the infected seedbed died soon after setting out in the field, especially of the susceptible varieties. To what extent this mortality was due to *F. lycopersici* and to what extent to other causes was not ascertained, consequently such plants are merely classified as died from undetermined cause (Table 3). Other seedlings were raised in an uninfected seedbed. Very few of these died without first becoming established.

The reaction of the varieties included in this test to *Fusarium* wilt is shown in table 3. The number of varieties tested was thirty-three and the average number of plants of each was forty-six, but varied from as few as 7 up to 194. The results with plants from infected and uninfected seedbeds not being strictly comparable are shown separately. In some cases where the same or similar varieties were included in both groups comparison indicates that the relative susceptibility of the varieties is approximately the same in the two groups although the plot from the infected seedbed showed a higher mortality among the young plants and more severe symptoms of the disease. In some varieties replicate one-row plots each containing about fifty plants were planted, these plots being separated as widely as possible. The results from such plots are shown separately (Table 3).

Field planting took place on June 18 in rows six feet apart with four feet between the plants in the row. Five weeks later many of the plants were severely wilted and in a dying condition. *F. lycopersici* was isolated from the diseased plants. Differences in the intensity of the *Fusarium* wilt symptoms among varieties were evident and became accentuated as the season advanced. As was expected the control variety Stone proved very susceptible, so much so that on October 16 over 50 per cent had died from wilt. Morse's San Jose Canner also proved very susceptible. On the other hand a large number of varieties proved to be resistant. Among these were Norton, Norduke and Marvel, thus confirming the results obtained at Riverside and La Mesa. Most of the varieties bred for wilt resistance by State Agricultural Experiment

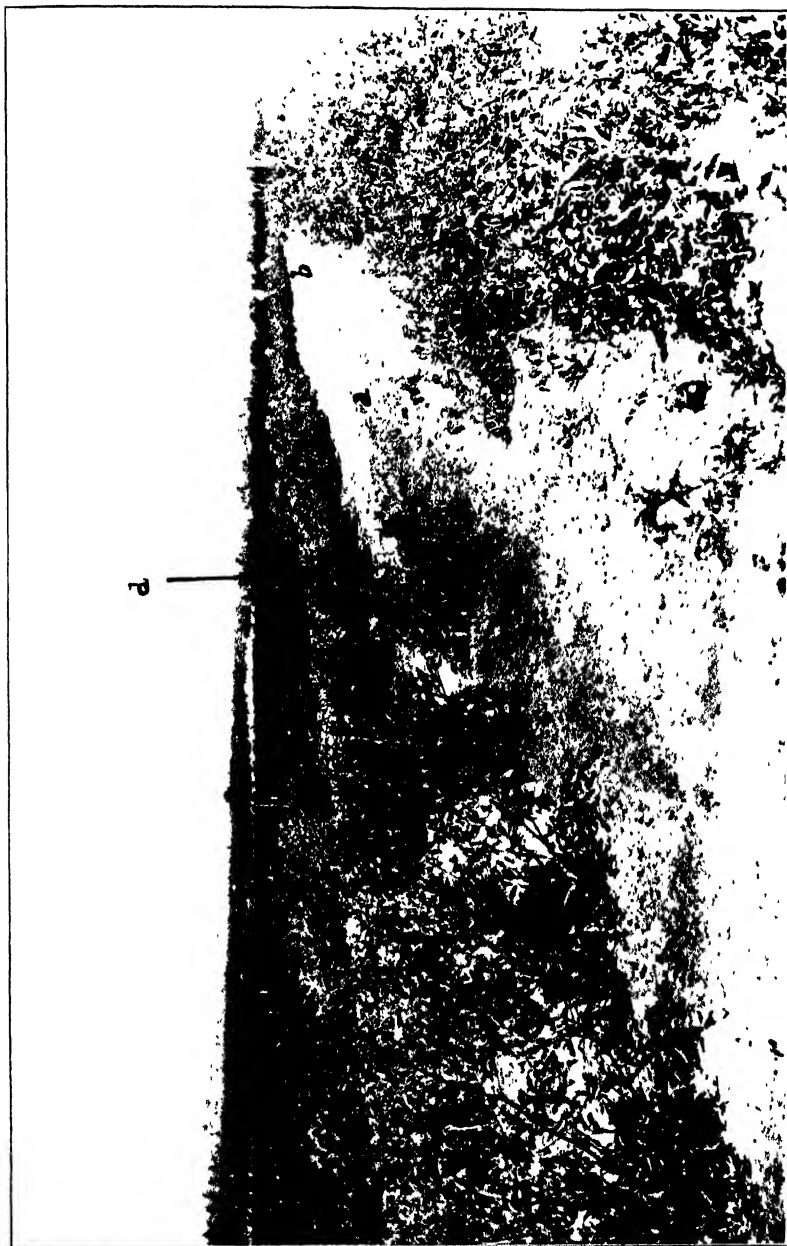
TABLE 3—Continued.

Plants from infected seedbed	Total number of plants		Apparently healthy		Slightly affected		Medium affected		Severely affected	Number died of Fusarium				Number died from undetermined cause		Per cent died from undetermined cause
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Prior to July 25	From July 25 to Aug. 21	From Aug. 21 to Oct. 16	Per cent died of Fusarium	Prior to July 25	From July 25 to Aug. 21	
Mo. 316, La. Red. sel. ³	32		30	94	1	3								1		3
Louisiana Pink ¹⁰	32		29	91	2	6								1		3
Mo. 105, Marvel sel. ²	10		9	90	1	10								1		3
Mo. 352, Marvel sel. ²	32		30	94	1	3								1		3
Mo. 226, Marvel sel. ²	22		17	77	1	5		2	9					2		9
Plants from uninfected seedbed																
Marvel ⁷	50		47	94	1	2								2		4
Globe ⁷	50		46	92	2	4		1	2					1		2
Globe ⁷	49		20	41	22	45		4	8		1			1		4
Globe ⁷	43		28	65	14	33		1	2							
Columbia ⁷	50		38	76	6	4						2	4	5	1	12
Norduke ⁷	48		45	94	1	2								1		2
Norduke ⁷	50		50	100												
Norton ⁷	50		42	84								1	2	6		12
Norton ⁷	45		35	79	2	4		1	2					5		11
Norton ⁷	50		44	88	1	2								2	2	8
Norton ⁷	49		41	84						1		2	6	2	1	6
Stone ⁷	50		1	2	6	12		11	22			27	58	3		6
Stone ⁷	43		1	2	4	9		12	28		1	21	52		4	9

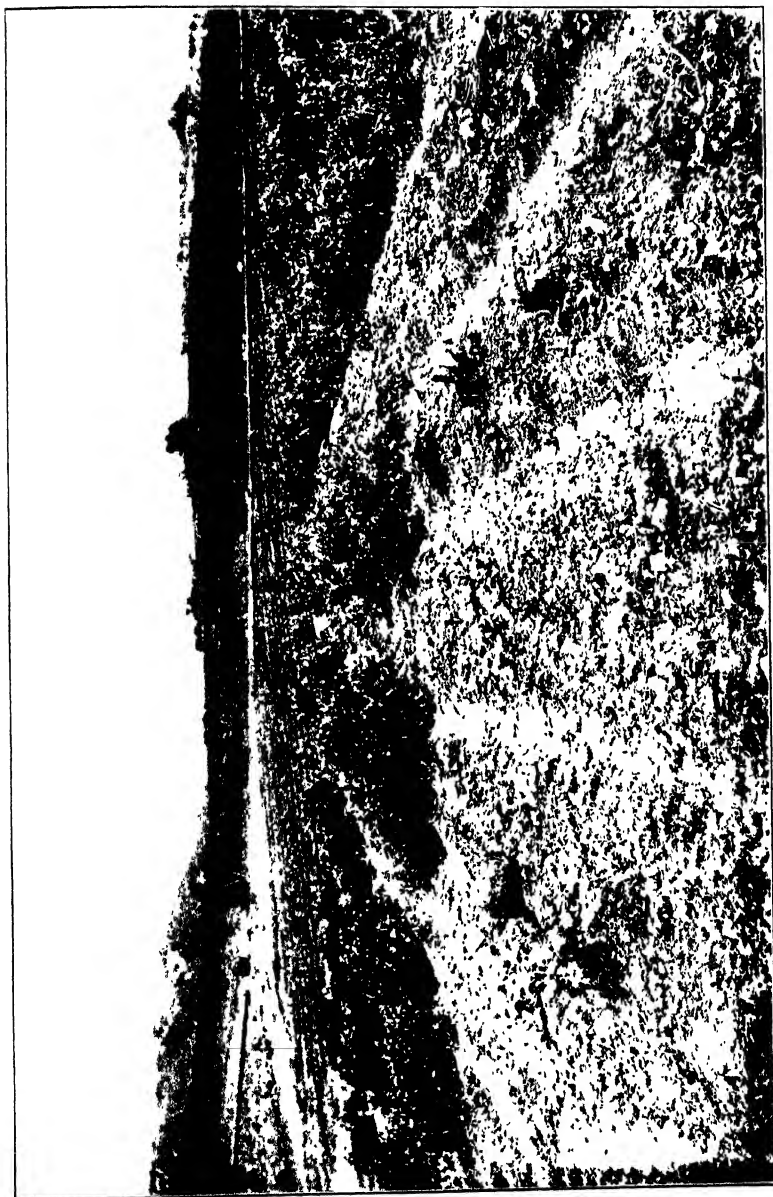
¹ From J. W. Lloyd, Ill. Agr. Expt. Sta. sel. by C. E. Durst.² From Ind. Agr. Expt. Sta.³ From J. T. Rosa, Calif. Agr. Expt. Sta.⁴ From H. R. Rosen, Ark. Agr. Expt. Sta.⁵ From Morse Seed Co.⁶ Selection from Jap Canner.⁷ From Haven Seed Co.⁸ Selection from Stone.⁹ From S. H. Essary, Tenn. Agr. Expt. Sta.¹⁰ From C. W. Edgerton, La. Agr. Expt. Sta.

Stations were also in the resistant class. Other varieties formed an intermediate class, being neither as susceptible as Stone nor as resistant as Norton. An Indiana Station selection (23.105) and Tennessee Beauty belong to this intermediate class. Other varieties again apparently bred for wilt resistance elsewhere appeared in this test to be almost as susceptible as Stone. Possibly then a few varieties, or perhaps more precisely selections, from other states fail to develop their wilt resistant qualities under California conditions. Whether or not these are selections showing definite wilt resistance in the places of their origin has not been ascertained, but if so they are exceptions as the majority of varieties have maintained their wilt resistance when introduced into California. The variety Globe was resistant although it showed more disease than Norton or Norduke. Two of the selections made by one of us in California tomato fields in the previous season are quite promising. One of these, 23087, a Stone selection, is in the resistant class, but hardly equal to Norton in this respect. The other is a selection from a susceptible variety largely grown in the Santa Clara Valley and known locally as Jap Canner. A first step has therefore been taken towards developing a wilt resistant strain of this variety so extensively grown in commercial fields of the State.

With regard to yield no exact data have been secured, but the production from resistant varieties far exceeded that from the susceptible. In particular the variety Norton produced a very good crop. In certain sections of California where Stone is now extensively grown Norton is far preferable for planting on wilt infested land. Norduke also gave a good yield although maturing later than Norton. A special merit of Norduke for California conditions, in addition to the wilt resistant quality, is its abundant foliage which should tend to diminish the injury from sunburn. Other varieties in the resistant class gave good yields, notably Illinois Imperial, Illinois New Century, Marvel, Columbia and Louisiana Pink. Certain of the resistant early varieties, such as Louisiana Red and Globe gave satisfactory yields, but the fruit was relatively small and the foliage too scanty which is a disadvantage wherever sunburn is a serious menace. The class intermediate in susceptibility to wilt was inferior to the resistant class in yield while the susceptible varieties gave practically no crop. Ninety-eight plants of Stone from the infected seedbed gave a yield hardly equal to that of one average plant of Norton.



Effect of artificial inoculation with *Fusarium lycopersici* at Riverside, Cal., in 1923; (a): inoculated San Jose Canner; (b): inoculated Stone, i.e. uninoculated San Jose Canner and (d) the same varieties inoculated with a non-pathogenic culture.



Behavior of resistant and susceptible varieties on the land badly infested with *Fusarium lycopersici* at La Mesa, Cal., in 1923. Stone in the foreground and Norton, Norduke and Marvel in the background.

SUMMARY

The reaction of a number of tomato varieties to the wilt fungus, *Fusarium lycopersici* Sacc., has been tested. Two methods of testing were used, artificial inoculation with pure culture of the fungus and natural field infection. In the former method two distinct cultures of *Fusarium* were employed, both having been isolated from wilted plants in California. One of these cultures proved to be parasitic, causing the typical *Fusarium* wilt disease. Three plots in places widely separated in Southern California and involving two methods of testing gave quite consistent results. The variety Norton proved resistant in all three places. Norduke, Marvel and a California selection from Stone (23.087) were resistant in both localities where tested. Most but not all of the varieties bred for wilt resistance at various Experiment Stations, also the variety Livingston's Globe, proved resistant to wilt when planted in badly infected soil in California.

PHYTOPATHOLOGICAL NOTES

An early report on infectious chlorosis.—Lawrence, John, A.M., Rector of Yelvertoft in Northampton-shire, and sometime Fellow of Clare-Hall in Cambridge. "The Clergy-Man's Recreation: Shewing the Pleasure and Profit of the Art of Gardening." Published in London in 1715. (The introduction, however, bears the date March 15, 1713.)

"Suppose a plain Jessamine Tree,¹ spreading itself into 2 or 3 branches from one common Stem near the Root. Into any one of these Branches in August inoculate a Bud taken from a yellow strip'd Jessamine, where it is to abide all Winter; and in the Summer, when the Tree begins to make its Shoots, you will find here and there some Leaves ting'd with Yellow, even on the other Branches not inoculated, till by degrees in succeeding Years the whole Tree, even the very Wood of all the Branches, shall be most beautifully strip'd and dy'd with Yellow and Green intermix'd. It is not material whether you cut off the Branch above the Inoculation to make the Bud it self shoot; for it will have the same Effect of tinging by degrees all the Sap of the Tree, as it passes by or through this Bud, and communicating its Virtue to the most distant and opposite Branches, tho' the Bud it self should not shoot out. Nay I have myself several times experienc'd that if the Bud do but live two or three Months, and after that happen to die, or be wounded by any Accident, yet even in that little time it will have communicated its Virtue to the whole Sap, and the Tree will become entirely strip'd. This Discovery undoubtedly proves the Circulation of the Sap. Q. E. D."

That this variation was recognized as pathological is shown by a citation from Richard Bradley, Professor of Botany in the University of Cambridge and Fellow of the Royal Society, "New Improvements of Planting and Gardening," of which the first edition was published in 1717, who refers to "the unwholesome Tincture communicated to the Plant from the striped Bud." Bradley's book has a chapter on blights, in which, among other things, he treats on the prevention of smut in wheat (p. 222). "The Receipt to prevent Wheat from being smutty * * * * teaches us first to wash the Wheat through three or four several Waters, stirring it round each time with a large Stick backwards and forwards with great Force, and with a Skimmer each time take off all the light Wheat. When this is done, put your Wheat into a Liquor prepared in this manner:

¹ This jessamine is in all probability *Jasminum officinale* Linn.

"Put into a large Tub, which hath a Tap, a sufficient Quantity of Water; then put as much Salt into it, as, when 'tis well stirr'd about, will make an Egg swim; then add as much more Salt as was before, and stir it very well; and to this put two or three Pounds of Allom beaten very fine, and stir it about.

"This you are to use as you do your ordinary Brines, only you must let your Wheat steep thirty or forty Hours, for less signifies nothing; tho' the common Opinion is, that steeping so long kills the Seed in the Wheat; but Experience teaches the contrary.

"You must take your Wheat out the Night before you sow it, and sift some slak'd Lime on it, which serves only to make it dry enough to sow. 'Tis necessary to add some more Water to the Brine in a Week or ten Days time, as it wastes, and Salt proportionable to the Water, and about a Pound of Allom.

"Note, Many Farmers steep their Wheat in a Brine, yet have Plenty of Smutty Wheat, because they don't make their Brine strong enough, and take their Wheat out too soon.

"Note also, Many Farmers have suffer'd greatly by Smutty Wheat, especially in a dear Year, when such Wheat will not sell for above Five or Six Shillings a Bushel; whereas that which is free from Smut, will sell for Ten, Eleven, or Twelve Shillings; and such Smutty Wheat being eaten chiefly by the poorer People, and being unwholesome, occasions Sickness; Therefore, for the Benefit of the Publick, this is printed."—W. A. ORTON.

Personals: Prof. G. B. Traverso, formerly vice-director of the Royal Station of Plant Pathology at Rome, on November first assumed the Professorship of Plant Pathology at the Royal School of Agriculture at Milan. His present address is R. Scuola Superiore di Agricoltura, Laboratorio di Patologia Vegetale, via Marsala, Milano, Italia.

REPORT OF THE FIFTEENTH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The fifteenth annual meeting of the Society was held at the University of Cincinnati, Cincinnati, Ohio, December 27, 1923 to January 1, 1924 inclusive, in conjunction with the American Association for the Advancement of Science and affiliated scientific societies. President G. R. Lyman presided and there were approximately 145, or 26 per cent of the members present. This is the largest annual gathering of the Society that has ever been held, the attendance at the Boston, Toronto and Chicago meetings being 95 (17 per cent), 85 (16 per cent), and 110 (21 per cent) respectively. The headquarters of the Society this year were at the Hotel Gibson at Cincinnati.

One hundred and fourteen papers were presented at the regular sessions of the Society. Eight papers were read at special sessions, and six papers of especial interest to members were given at the Potato Scab symposium of the Potato Association of America. The number of papers on the regular program at Boston in 1922 was 79, at Toronto in 1921, 97, and at Chicago in 1920, 80. Abstracts of the papers were printed in *Phytopathology* (*Phytopath.* 14: 24-66. Jan. 1924.) and a popular summary of the meeting has appeared in a special number of *Science*. (*Science* 59: 98-100. Feb. 1, 1924.)

There were three joint sessions with other societies. The regular joint session with Section G of the American Association for the Advancement of Science was held on Friday afternoon, December 28 and the following papers were presented: *The Fluorescent Colors of Plants, their Occurrence and Meaning*, by F. S. Lloyd, retiring Vice President of Section G; *The Relation of Environment to Disease of Plants*, by L. R. Jones; *Recent Advances in Cytology*, by L. W. Sharp; and *Cell Activity and H-ion Concentration*, by B. M. Duggar. On Saturday afternoon the Society combined programs with the Mycological Section of the Botanical Society of America in the presentation of general mycological and pathological papers and on Saturday forenoon joined with the American Society of Horticultural Science and the Horticultural Inspection Section of the American Association of Economic Entomologists in a symposium on the subject of crown gall inspection. The purpose of this symposium was to weigh the evidence concerning the economic importance of crown gall, to review the inspection methods now in use, and to formulate recommendations for the improvement of these methods. Four members of a special committee, M. J. Dorsey, representing the horticulturists, Henry B. Chase, representing the nurserymen, Harry F. Dietz, a nursery inspector, and I. E. Melhus, a plant pathologist, presented papers embodying their views on crown gall inspection and giving the results of questionnaires that previously had been submitted to the membership of the societies and associations represented. After the symposium the committee worked out a set of rules or principles which may be applied in such a way as to bring about more uniform and more satisfactory methods than those now in use. This report, which represents a definite accomplishment of the meeting, was adopted by this Society and by the American Association of Economic Entomologists. It has been made available through publication in *Phytopathology* and the official organs of the nursery associations, as well as by means of the distribution of mimeographed leaflets.

The annual dinner of the Society was held on Saturday evening, December 29, at the Hotel Gibson, and was attended by one hundred and fifty-six persons, of whom one hundred and forty were members of the Society.

The following officers were elected:

President, F. D. Fromme, Virginia Polytechnic Institute, Blacksburg, Va.

Vice President, J. H. Faull, University of Toronto, Toronto, Canada.

Councilor for two years, C. R. Orton, Pennsylvania State College, State College, Pa.

Councilors for one year (chosen by the Divisions of the Society): B. T. Dickson, Macdonald College, Quebec, representing the Canadian Division; F. D. Heald, State College of Washington, Pullman, Washington, representing the Pacific Coast Division; and C. A. Ludwig, Agricultural Experiment Station, Clemson College, South Carolina, representing the Southern Division.

The members of the Editorial Board of *Phytopathology*, whose terms expired at the close of 1923, namely: Perley Spaulding, Editor-in-Chief; L. L. Harter and N. J. Giddings, Editors; and G. R. Bisby, J. Franklin Collins, L. R. Hesler, and A. G. Johnson, Associate Editors; were requested to continue to serve until such time as new editors and associates can be carefully selected by the Council; Business Manager for one year, R. J. Haskell, U. S. Department of Agriculture, Washington, D. C.; Advertising Manager for one year, R. G. Pierce, U. S. Department of Agriculture, Washington, D. C.

Member of the Editorial Board of American Journal of Botany for two years to complete the unexpired term of D. Reddick, resigned (chosen by the Council): G. R. Bisby, Agricultural College, Winnipeg, Manitoba, Canada.

Representatives on the Council of the American Association for the Advancement of Science for one year (chosen by the Council): G. P. Clinton, Agricultural Experiment Station, New Haven, Connecticut, and W. A. Orton, U. S. Department of Agriculture, Washington, D. C.

Representatives on the Council of the Union of Biological Societies for one year (chosen by the Council): the Editor of *Phytopathology* and the Secretary of the Society.

Members of the Advisory Board (chosen by the Council): N. J. Giddings, University of West Virginia, Morgantown, West Virginia, for three years to succeed C. R. Orton as Commissioner for the Northeast, and M. W. Gardner, Indiana Agricultural Experiment Station, Lafayette, Indiana, for three years to succeed G. H. Coons as Commissioner for the Middle West.

Trustee of the Tropical Plant Research Foundation for five years (chosen by the Society): L. R. Jones, University of Wisconsin, Madison, Wisconsin.

Representative on the committee for an International Botanical Congress in 1925 (chosen by the Council): H. H. Whetzel, Cornell University, Ithaca, N. Y.

Representatives on crown gall committee (chosen by the Society): F. C. Stewart, Agricultural Experiment Station, Geneva, N. Y., and I. E. Melhus, Agricultural Experiment Station, Ames, Iowa.

REPORT OF THE TREASURER FOR 1923

STATEMENT OF ACCOUNTS FOR 1923, AS OF DEC. 20, 1923

Receipts:

Balance from 1922.....	\$1,326.78
Annual dues.....	3,426.00
Contribution to cover cost of Phytopathology to European pathologists.....	105.00
Subscription received with annual dues.....	5.50
Excess dues.....	9.04

Subscriptions to Oberly Memorial Fund received with annual dues.....	53.01
Interest on checking account.....	23.34
Interest on time deposit of \$1500, 6 mos. at 4%.....	30.00
	<hr/> \$4,978.67

Expenditures:

Member subscriptions transferred to Phytopathology.....	\$1,808.00
Secretarial work.....	163.25
Stationery, stamped envelopes, printing.....	269.00
Subscriptions transferred to Phytopathology.....	5.50
Postage stamps.....	23.68
Supplies, rubber stamps, a/c books, telegrams.....	8.27
Expressage on manuscript from Editor-in-Chief.....	1.14
Excess dues returned.....	4.00
Secretary-Treasurer's travel and miscellaneous expenses.....	118.47
Expenses of special committee.....	58.36
Check returned by bank.....	4.25
Amount transferred to sinking fund for investment.....	415.58
Oberly Memorial Fund transferred to Mary K. Bryan.....	97.33
	<hr/> \$2,976.83
Balance.....	<hr/> \$2,001.84

Amount of above receipts for 1924 and 1925..... \$1,718.65

Sinking Fund:

Amount due for 1922.....	\$ 5.00	
Amount due for 1923.....	35.00	40.00
Amount due Oberly Memorial Fund.....		3.16
Amount due Phytopathology for Vol. XIII to European Pathologists.....	44.02	
	<hr/>	1,805.83
Actual balance for 1923.....		<hr/> \$ 196.01

The undersigned committee appointed for this purpose have audited the accounts of The American Phytopathological Society and have found them to be correct.

N. J. Giddings

C. R. Orton

Oberly Memorial Fund:

The request that each member add twenty-five cents to his 1923 annual dues as a personal contribution to the fund for the Eunice R. Oberly Memorial Prize met with a pleasing response. In the Secretary-Treasurer's report for 1922 receipt of \$47.48 was acknowledged and since that time \$53.01 has been received, making a total of \$100.49 contributed by this Society. The committee in charge of this fund informs us that the total amount received from all sources slightly exceeds one thousand dollars. The prize will take the form of a cash award, to the amount of the interest from the fund, to the compiler of the best bibliography for each year in the field of agriculture or the natural sciences.

Membership:

On December 20, 1923, the Society had 557 members in good standing: 90 life sustaining and 467 regular, as opposed to 553 in 1922, 539 in 1921, and 495 in 1920. During the year 25 members were suspended for non-payment of dues and 29 new paid-up members were added, making a net gain of 4. At the Cincinnati meeting 88 new members were elected.

REPORT OF THE BUSINESS MANAGER OF PHYTOPATHOLOGY FOR 1923
STATEMENT OF ACCOUNTS FOR 1923, AS OF DEC. 20, 1923

Receipts:

Balance from 1922.....	\$1,621.28	
Member subscriptions transferred from Society.....	1,808.00	
Subscriptions.....	2,012.80	
Sales.....	398.31	
Excess sales.....	7.50	
Advertising, 1921.....	45.60	
Advertising, 1922.....	182.53	
Advertising, 1923.....	504.77	
Interest on invested sinking fund.....	225.00	
Interest on time deposit.....	4.00	
Balance due sinking fund to January 3, 1923.....	415.58	
Time deposit redeposited in checking account.....	100.00	
		<hr/>
		\$7,325.37

Expenditures:

Manufacturing Phytopathology:

Vol. XII, No. 10.....	\$240.76	
Vol. XII, No. 11.....	297.44	
Vol. XII, No. 12.....	404.06	
Vol. XII, Index.....	91.41	
	<hr/>	\$1,033.67
Vol. XIII, No. 1.....	\$389.94	
Vol. XIII, No. 2.....	350.42	
Vol. XIII, No. 3.....	355.08	
Vol. XIII, No. 4.....	291.85	
Vol. XIII, No. 5.....	429.13	
Vol. XIII, No. 6.....	239.49	
Vol. XIII, No. 7.....	304.77	
Vol. XIII, No. 8.....	289.78	
Vol. XIII, No. 9.....	226.05	
Vol. XIII, No. 10.....	392.04	
	<hr/>	3,268.55

\$4,302.22 \$4,302.22

Miscellaneous Journal expenses (Dix lists, etc.).....	40.85
Second class postage on Phytopathology.....	45.40
Secretarial work.....	108.25
Printing billheads.....	14.00
Postage.....	10.00

Postage and clerical work for Advertising Manager.....	4.92
Excess sales refunded.....	7.50
Duplicate subscription refunded.....	5.00
Check returned by bank.....	5.00
Postage on back volumes sold by C. E. Temple.....	9.13
Sinking fund invested with accrued interest.....	502.73
	<hr/> \$5,055.00

Balance.....	\$2,270.37
Amount of 1924 subscriptions included in above receipts.....	319.75

Actual balance for 1923..... \$1,950.62

The undersigned committee appointed for this purpose have audited the accounts of Phytopathology and have found them to be correct.

N. J. Giddings,
C. R. Orton

Statement concerning Sinking Fund, as of Dec. 21, 1923

Amount invested in mortgage notes

McLachlen note (6%).....	\$ 500.00
Hobson note No. 1 (6%).....	500.00
Hobson note No. 2 (6%).....	1,000.00
Kaulbeck note No. 1 (7%).....	500.00
Kaulbeck note No. 2 (7%).....	500.00
Phelps note (7%).....	500.00
	<hr/> \$3,500.00

Amount in Phytopathology account due sinking fund..... 15.58

Amount in Society's account due sinking fund..... 40.00

\$3,555.58

The statement made in the Business Manager's report of last year that, "The journal of the Society has passed its financial crisis safely and is now on firm ground," is borne out by the experience of 1923. We have printed 562 pages with an index and have come out with an actual balance of six hundred and forty-three dollars in excess of last year. This increase has been due largely to lower manufacturing costs. It should also be noted, however, that one more number of *Phytopathology* was paid for in 1922 than in 1923, so that the only actual gain for the year is represented by about three hundred dollars.

The income from advertising is an appreciable one and a prospective source of much greater profit. The receipts from advertising in 1920 amounted to \$193.93, in 1921—\$309.32, in 1922—\$519.06, and in 1923—\$595.77. This steadily increasing sum is encouraging and leads us to look on advertisements as a promising source of income for use in enlarging and improving *Phytopathology* without calling on the members for further financial assistance. It is hoped that during 1924 a considerable number of new advertisers may be secured, but to do this the assistance of the individual members is necessary. It is manifestly impossible for any one person, such as our advertising manager at Washington, to secure the advertisements of all the concerns that should advertise in *Phytopathology*. Therefore, each member is urged to do what he can to

help in the matter. A half page advertisement for an entire year is almost as good as a sustaining life membership. The following suggestions are offered by Roy G. Pierce, Advertising Manager.

1. That members trade with advertisers, if possible.
2. That you mention *Phytopathology* when ordering from advertisers.
3. That when dealing with concerns you suggest their advertising in *Phytopathology*.
4. That you secure the advertisements of any companies, firms or individuals with which you have particular influence.

For your convenience the advertising rates are given herewith.

Space	For each insertion if type is set	For each additional insertion if copy is not changed	For each insertion if plate is furnished requiring no composition
1 page.....	\$15.00	\$13.00	\$13.00
1/2 page.....	8.00	7.00	7.00
1/4 page.....	5.00	4.50	4.50
1/8 page.....	3.00	2.75	2.75

Inside covers and pages facing reading matter 20 per cent advance.

Back cover page 40 per cent advance.

REPORT OF THE EDITOR-IN-CHIEF OF PHYTOPATHOLOGY

With the end of the present calendar year, the present Editor-in-Chief finishes his three-year term. Because of his resignation at this time it may be well to summarize our operations for the years 1921-23, inclusive.

In the year preceding, namely 1920, 554 pages of text were published. This, however, included 54 pages of the Oberly bibliography of plant pathology, so that the actual amount of other matter was exactly 500 pages.

In 1921, the costs of publication increased greatly and finances were badly strained. An effort was made by the Editor to reduce these costs as far as possible by condensation of papers and elimination of all illustrations which were not absolutely necessary. Nevertheless in 1921 we published*516 pages of text. In 1922, 585 pages, and in 1923, 562 pages were published. It should be said that on December 30, 1920, our publication of the Oberly bibliography was discontinued by vote of the Society, because of a definite understanding with *Botanical Abstracts* that when that publication was thoroughly established it should be the reference publication for us as well as for botanists. It will be noted that the actual pages published in 1923 are slightly more than were published in 1920. Besides the 562 pages of text we have published 23 plates and 98 text figures, approximately the usual number. It should be noted that of the 562 pages of text, 37 pages have been given up to abstracts of the Society and its Divisions.

Beginning with 1921 we have adopted a policy of verifying citations in manuscripts which are submitted for publication. This has been done through the very kind consent and cooperation of the Library of the Bureau of Plant Industry. It has resulted in eliminating many mistakes and has moreover secured for us uniformity in methods of citing. In the same connection it should be said that our moral obligations to *Botanical Abstracts* led to the adoption of what is essentially their method of citing and of printing citations. It seemed best to adopt some definite plan of citation, and it also seemed desirable to have this plan uniform with that of *Botanical Abstracts*.

The Editor would call attention to the increasing patronage of our Journal by foreign workers. This we believe is desirable and should be continued so long as it is feasible, as it must result in increasing interest of foreign workers in our Journal, and in the work which is being done in this country, and must lead to an increased foreign membership and subscription list.

A department of the Journal which is rather neglected at present and which we believe should be used more is the "Phytopathological Notes." As stated above, the Editor's policy during this term has been that of restricting matter published so far as seemed feasible to new investigations and their results. Although the cost of publication has begun to drop, the Editor believes that this policy should be continued.

Because of the absence of the Editor-in-chief in Europe, most of 1922; Dr. L. L. Harter acted as Editor-in-chief for that year, ably carrying on the work under difficult conditions.

REPORT OF THE ADVISORY BOARD

The Advisory Board report was made to the Council by its Chairman, C. R. Orton, and after its approval was referred to the Society and was adopted as follows:

SUMMER CONFERENCES

The fifth annual summer meeting of the Society was held in Western New York and Ontario, Canada, on July 9-12, inclusive, with an attendance of sixty-nine members of the Society and about twenty guests. The program arranged by the Advisory Board was under the direct charge of Dr. M. F. Barrus for New York and Dr. J. H. Faull for Ontario. In Dr. Faull's absence Prof. J. E. Howitt served as chairman *pro tempore* for the Ontario program. Dr. Barrus was ably assisted by H. E. Thomas and W. H. Rankin and Dr. Faull had the assistance of J. E. Howitt and J. F. Hockey in arranging the plans in Ontario. To these men, who so ably arranged and carried out the program for this summer meeting, the Society owes its thanks. A more complete account of the meeting was published in *Phytopathology* 13: 507-508. 1923.

PHYTOPATHOLOGICAL INSTITUTE

No further progress has been made on this project which is under the leadership of Dr. E. C. Stakman. The Thompson Institute for Plant Research has initiated studies on the mosaic problem and the Crop Protection Institute has carried on some fundamental studies on sulphur as a fungicide. The further advancement of fundamental researches through institutional agencies should be encouraged but our interest in the projection of an American Institute should be continued.

COMMITTEE ON COOPERATION WITH THE NATIONAL RESEARCH COUNCIL

The Advisory Board through its chairman made a report of its activities to the Division of Biology and Agriculture of the National Research Council at the April meeting of the Division in Washington. It was voted at that meeting to continue the committee on cooperation in phytopathology together with two or three other similar committees. However, since that meeting it has been decided to discontinue this committee on cooperation, as represented by the Advisory Board, but to maintain our contact with the Research Council through our representative, the chairman of the Advisory Board.

SPECIAL RESEARCH AND INVESTIGATIONAL PROJECTS

Rust Project. The Arthur rust project was initiated September 1, 1922, through the joint efforts of the Division of Biology and Agriculture, Office of Cereal Investigations, U. S. D. A.; Indiana Agricultural Experiment Station; the Virginia Polytechnic Institute; the Pennsylvania State College; and the Arthur Committee. Plans for the prosecution of this project were all worked out when Dr. Arthur was taken ill last spring and postponement was necessary. These plans were resumed in November, 1923 when Dr. F. D. Kern spent three weeks at the Indiana Experiment Station assisting Dr. Arthur in the preparation of the book on "Plant Rusts." Dr. F. D. Fromme has arranged to spend the month of January with Dr. Arthur and later in the spring C. R. Orton is expecting to contribute a month to this project. This project should proceed rapidly from now on.

Seed Borne Parasites. Since the last report on this project the committee composed of C. R. Orton, M. F. Barrus and M. T. Munn has prepared a preliminary list of seed borne parasites which has been put in mimeographed form and circulated to leading plant pathologists in the United States and Canada for criticism. Numerous additions were made and the list now totals over 160 with much of the foreign literature untouched.

Further contacts have been made with the American Seed Trade Association and a prospectus for research on the project has been submitted to that Association for consideration by a special committee operated by their President.

The subject was presented to the Canadian Branch of the American Phytopathological Society at their recent meeting at Kingston, Ontario, December 20, by C. R. Orton. Considerable interest is being aroused regarding this project and it is believed that some way will be found soon for initiating researches bearing upon it. The seed analysts are also much interested in the project.

Sulphur Investigations. The sulphur investigations have been continued under the leadership of Dr. B. M. Duggar and Prof. P. J. Parrott and administered by a special committee of the Crop Protection Institute. G. H. Coons and C. R. Orton have continued to serve on this committee. Following the resignation of Dr. H. C. Young, Mr. L. E. Tisdale was appointed to continue the fungicidal investigations which are being continued at the Missouri Botanical Garden. The field tests have been conducted in New York and Pennsylvania during the past season and these will be more fully elaborated next season. The insecticidal phases under the direction of Prof. Parrott are being carried out by Mr. Hartzell. Excellent progress is being made in both phases of the investigations.

Seed Treatment. The seed treatment project under the Crop Protection Institute has been continued under the cooperative plan adopted in 1922. These tests have been carried out with copper carbonate and numerous other disinfectants in many stations in the United States and Canada. Wheat and oats have been the seed used in most cases. Excellent results have been obtained with copper carbonate in practically all cases. The reports are now being received. E. C. Stakman and C. R. Orton have served as the committee on this project.

Furfural Investigations. The Crop Protection Institute has received a fund from the Quaker Oat Company for the purpose of investigating the fungicidal properties of *furfural*, a by-product of their manufacture. This investigation will be conducted at Iowa State College under Dr. I. E. Melhus. The fellowship has not yet been awarded. C. R. Orton has served as Chairman of the committee on this subject.

Scalecide Investigations. These investigations financed by the B. G. Pratt Company under the Crop Protection Institute were started last spring in Massachusetts, Pennsylvania and West Virginia. Mr. J. W. Miller has been conducting the studies which include a study of the effects of Scalecide upon growth and fire blight. C. R. Orton has served as chairman of the committee for the Crop Protection Institute.

CROP PROTECTION INSTITUTE

Coordinative relations have been continued with the Crop Protection Institute, G. H. Coons and C. R. Orton having served during the past year as members of the Board of Governors of the Institute. It appears desirable to continue and to strengthen these relations with the Institute which is growing rapidly and each year filling a more important role in the phytopathological field.

At the Cincinnati meeting M. F. Barrus, the new chairman of the Advisory Board, was chosen as a member of the Board of Governors of the Institute for a term of three years to take the place of F. D. Fromme whose term expired. The other two members of the Board of Governors are C. R. Orton (term expires 1925) and G. H. Coons (term expires 1924).

CROWN GALL REPORT

F. C. Stewart read the report of the committee on crown gall inspection of which he was chairman. It was unanimously adopted and it was voted that the report be published in *Phytopathology* and the official nursery association publications. It was further voted that it was the judgment of the American Phytopathological Society that the committee should be continued and that F. C. Stewart and I. E. Melhus continue to represent the Society on that committee. The report was published in the March, 1924, number of *Phytopathology*.

RESOLUTIONS

A committee on resolutions, composed of E. C. Stakman, J. I. Lauritzen and L. R. Hesler submitted the following resolutions.

1. Dr. John A. Elliott, Plant Pathologist, University of Arkansas, died January 18, 1923.

Dr. M. P. Henderson, Dean of the College of Arts and Science, and Professor Biology, Brigham Young University, died in the late autumn of 1923.

On account of their scientific achievement and personal qualities, they won the professional respect and personal friendship of their colleagues. The American Phytopathological Society records its sense of great loss in the death of these members.

2. *Resolved:* that the American Phytopathological Society endorse the sentiments expressed in the Resolution of the Washington Academy of Science regarding a more liberal policy on the part of the government in paying expenses of scientific men to national and international scientific meetings.

3. The American Phytopathological Society wishes to express its sincere thanks to Mr. C. G. Lloyd for the delightful hospitality which he extended to the members of the Society who visited his museum and library.

4. The American Phytopathological Society wishes to express its appreciation to the University of Cincinnati, especially to the Committee on Local Arrangements for the excellence of the arrangements provided for our meetings; and to the citizens of Cincinnati for their kindness and hospitality during our visit.

MISCELLANEOUS BUSINESS

The secretary's report of the fourteenth annual meeting, held at Boston, was adopted without correction as published in *Phytopathology* 13, April, 1923.

The Society voted to hold its sixteenth annual meeting at Washington, D. C., December 20, 1924 to January 3, 1925 in conjunction with the American Association for the Advancement of Science and other biological societies.

The Society authorized the Council to spend such sums as are feasible and necessary to further the work of the committee on an International Congress. The committee is composed of B. M. Duggar, representing the botanists, H. C. Cowles, representing the ecologists, and H. H. Whetzel, representing the plant pathologists.

On Sunday morning, December 30, 1923 an informal meeting was held at the Hotel Gibson at which the subject of the printing of abstracts and the character of the program at our winter meetings was discussed. A committee, composed of E. C. Stakman, F. D. Fromme, B. T. Dickson, H. H. Whetzel, and R. J. Haskell, selected at that time, brought in the following report which was adopted by the Society at its regular business meeting. It was voted:

1. That the publication of abstracts be continued.
2. That in the near future the Secretary notify each member of the Society that hereafter only those abstracts which embody definite results will be published, and that this statement again be sent in the fall to each member, along with the announcement regarding the submission of abstracts.
3. That the time limit for the receipt of abstracts be November 1.
4. That all abstracts be submitted to an editorial committee of at least three, selected by the chief editor of *Phytopathology*, and that this committee edit the abstracts in the same manner as original articles published in *Phytopathology* are edited.
5. That there be a program committee consisting of the president, secretary, and chairman of the Advisory Board.
6. That the program committee arrange for at least one-half day session for the presentation of special papers on strictly pathological subjects.
7. That arrangements be made for at least some simultaneous sessions held in close proximity to each other in order to provide for informal discussion by smaller groups.

At an informal meeting of the Society at the Gibson Hotel on Sunday evening, December 30, the matter of nomenclature for biological or specialized forms of fungi was discussed. At the conclusion of that session the following motion was passed by those present.

"It is the sense of this meeting that we continue to recognize species on morphologic grounds and that if we recognize varieties in the fungi we recognize them on morphologic grounds; that we designate the entities which are recognized by physiological specialization as physiological races; that we recognize one category of physiological specialization, and that scientific names be not attached to these except where historical precedent or necessity requires."

This motion was read before the Society at its regular business meeting and it was voted that the President select a committee of two to cooperate with other biological societies in these nomenclature problems. C. L. Shear and E. C. Stakman were appointed. W. A. Orton reported progress in the development of the Tropical Research Foundation (formerly designated as the Tropical Phytopathological Institute or Tropical Plant Research Institute). The Foundation has received the approval of the National Research Council. The organization calls for seven trustees, one of

whom shall represent the National Research Council, and another the American Phytopathological Society. The Society chose L. R. Jones as its trustee for a term of five years and designated its Advisory Board as its committee on cooperation with the Tropical Research Foundation. The special committee of the Society and the National Research Council on research in the tropics, of which W. A. Orton is chairman, was continued by vote of the Society.

A communication from Dr. Quanjer of Holland regarding a proposed international phytopathological journal was brought to the attention of the meeting by W. A. Orton. It was voted that a committee of five composed of C. L. Shear, W. A. Orton, Haven Metcalf, F. D. Fromme, and the Editor-in-chief of *Phytopathology* offer to Dr. Quanjer the facilities of *Phytopathology* and take up with him further details concerning the matter.

The Society voted to dispense with the annual summer meeting during 1924 and to encourage the members to go to the meeting of the British Academy of Science at Toronto in August and that the attending botanists be invited to visit our laboratories.

One of the Cincinnati radio stations extended the Society an invitation to broadcast information concerning the meetings. This invitation was accepted and L. R. Jones, C. L. Shear, H. H. Whetzel, and W. A. McCubbin were designated to send out the information. The motion was unanimously carried that Miss Mary G. Van Meter, assistant to the Secretary-Treasurer and Business Manager, be given a complimentary membership in the Society for as long a period as she continues in her present position.

R. J. HASKELL, *Secretary*.

The March number of Phytopathology was issued April 12, 1924.

PHYTOPATHOLOGY

VOLUME XIV

NUMER 5

MAY, 1924

SPECIES OF FUSARIUM ISOLATED FROM ONION ROOTS

CHRISTOS P. SIDERIS

WITH PLATES IX TO XI

INTRODUCTION

In a study, on the determination of the causal organism of the pink root disease of onions, different species of *Fusarium* were isolated from roots showing symptoms of the disease. The morphological behavior of the different species was studied on culture media such as Wollenweber (6, 7) and Sherbakoff (3) used. New culture media, introduced by the writer, were used occasionally for the study of certain characters.

Certain new species and varieties were found among the different organisms. These are described and named. Those of the organisms, however, which have been described and named by previous investigators are given only a short mention in this paper. The writer is indebted to Dr. C. D. Sherbakoff for the determination of many of the organisms listed in this paper and for other very helpful suggestions.

FUSARIA ISOLATED

The different *Fusarium* species, isolated from onion roots with and without symptoms of the pink root disease, were studied in their morphological characters and physiological behavior in the manner followed by previous investigators. They were found to belong to four sections, *viz.*, *Elegans*, *Discolor*, *Martiella* and *Moniliform*, and to twenty species and varieties. To those of the organisms whose identity could not be established through the available literature, the writer assigned new names.

The different organisms are segregated in this presentation into two groups: (1) into species described by previous investigators, and (2) new species. Both previously described and new species and varieties are illustrated in plates IX, X and XI.

SPECIES DESCRIBED BY PREVIOUS INVESTIGATORS

Section Elegans

F. oxysporium Seht., (3) Pl. IX; *F. mali* Taub., (5) Pl. IX; *F. redolens* Wr., (3, 7) Pl. IX; *F. lutulatum* Sher., (3) Pl. IX; *F. oxysporium* var.

resupinatum Sher., (3) Pl. IX; *F. oxysporum* var. *longius* Sher., (3) Pl. IX; *F. orthoceras* var. *triseptatum* Wr., (6) Pl. IX; *F. angustum* Sher., (3) Pl. X.

Section Discolor

F. discolor Ap. et Wr., (1, 3) Pl. IX; *F. discolor* var. *sulphureum* Ap. et Wr., (1, 3) Pl. X; *F. culmorum* (W. Smith) Sacc., (3) Pl. X.

Section Martiella

F. radicola Wr., (3) Pl. X; *F. Martii* Ap. et Wr., (3) Pl. X.

Section Moniliform

F. moniliform Sher., (4) Pl. X.

NEW SPECIES

Section Elegans

***Fusarium cromyophthoron* n. sp.**

Diagnosis.—Conidia (Pl. IX and XI) 3-, 4-, and 5-septate, 3-septate more common, occur in sporodochia or pionnotes, in masses salmon colored; size of 3-septate $37 \times 3.25 \mu$, 4-septate $45 \times 3.75 \mu$ and 5-septate $55 \times 4 \mu$. Chlamydospores terminal and intercalated, single and catenulate, size 7μ in diameter. Sclerotia colorless not reappearing under prolonged cultural conditions. Ascigerous stage unknown.

F. cromyophthoron produces a perfect pinnotal stage and differs slightly from *F. lycopersici* Sacc. in the size of its conidia; in the latter the conidia are longer and the colorless sclerotia are considered as a constant morphological character.

Habitat.—On roots of onions with symptoms of pink root disease and on onion bulbs with powdery rot. Occurs in the Delta district near Stockton, California.

***Fusarium rhizochromatistes* n. sp.**

Diagnosis.—Conidia (Pl. XI) 3-, 4-, 5- and 6-septate, 3-septate more common, occur in sclerotial and plain sporodochia and pseudopionnotes, in masses salmon colored. Chlamydospores terminal and intercalated, single and catenulate, size 7 to 10μ . Sclerotia 3 to 6 mm. of a brownish blue color at the center of the colony and small bluish 1 to 3 mm. at the margins. Aerial mycelium well developed, hyphae from 5 to 10 mm. long, distinct, not interwoven or forming cormia like structures. Substratum ranging between peach and orange colors. Ascigerous stage unknown.

Habitat.—On roots of onions, Irish potatoes and millet with symptoms of pink root disease. Occurs in the Delta district near Stockton, California.

Fusarium rhizochromatistes var. **microsclerotium** n. v.

Diagnosis.—Conidia (Pl. XI) similar in size and curvature as in *F. rhizochromatistes*. It differs in the size of the sclerotia which measure from 1 to 3 mm. of a bluish color. Sporodochia not emerging from sclerotia.

Habitat.—On roots of onions with symptoms of pink root disease. Occurs in the Delta district near Stockton, California.

Fusarium sclerostromaton n. sp.

Diagnosis.—Conidia (Pl. XI) 3-, 4- and 5-septate, 3-septate more common, other forms rare, occur in sporodochia emerging from a continuous rough plectenchymatic layer covering the entire surface of the colony during the early stages of growth, in masses salmon colored. Chlamydospores terminal and intercalated, single and catenulate, size 7 to 10 μ . Sclerotia growing over the plectenchymatic layer first colorless and later turning bluish, size 1 to 3 mm. Aerial mycelium growing over the plectenchymatic layer in irregular masses, length of hyphae from 3 to 5 mm. interwoven in cottony like masses. Substratum of a grayish peach to grayish orange color, Aseigerous stage unknown.

Habitat.—On roots of onions with symptoms of pink root disease. Occurs in the Delta district near Stockton, California.

Fusarium loncheceras n. sp.

Diagnosis.—Conidia (Pl. XI) 3-, 4-, 5- and 6-septate, 5-septate more common, size of 5-septate $47 \times 3.25 \mu$, slightly or not arcuate, lanceolate, occur in eupionnotes of honey and orange colors. Chlamydospores terminal and intercalated, the former more common, single and catenulate, size 5 to 8 μ . No sclerotia. Aerial mycelium absent or slightly developed at the margins of the colony. Substratum ranging between peach and orange colors. Aseigerous stage unknown.

F. loncheceras has certain similarities with *F. angustum* Sher., it differs, however, from the latter in the color of its conidia and substratum and in the septation of the conidia in proportion to their size.

Habitat.—On roots of onions with and without symptoms of pink root disease. Occurs in the Delta district near Stockton, California.

Fusarium loncheceras var. **microsporon** n. v.

Diagnosis.—*F. loncheceras* var. **microsporon** (Pl. X) differs from *F. loncheceras* in the size of its pionnotal conidia and the production of a greater number of 3-septate than 5-septate conidia. Substratum of a clayish to brickish color. Pionnotes forming a thinner layer than in *F. loncheceras*. Aerial mycelium absent in carbohydrate media but slightly developed in protein media; hyphae aggregate forming coremia like structures.

Habitat.—On roots of onions with symptoms of pink root disease. Occurs in the Delta district near Stockton, California.

BEHAVIOR OF FUSARIA IN DIFFERENT MEDIA

Culture Media

The methods, employed for the systematic study of the different morphological characters developed by *Fusaria*, consisted in growing the particular organism on different nutrient substances and observe its behavior thereon. The culture media used in these studies were: (1) dextrose agar, (2) dextrose bean agar, (3) potato tuber plugs steamed, (4) steamed Melilotus stems, (5) steamed blackberry stems, (6) steamed rice grains, and (7) beef extract agar.

The first culture medium, dextrose agar, was prepared with addition of 1.75 per cent agar-agar in a solution containing the following: distilled water 1000 c.c., dextrose 20 grms., MgSO_4 2.12 grms., $\text{Ca}(\text{NO}_3)_2$ 0.71 grms., KH_2PO_4 1.36 grms., and $\text{Fe}(\text{NO}_3)_3$ 1 c.c. of a 5 per cent solution. Half liter portions of the solution were adjusted to different H-ion concentrations by the addition of appropriate reagents (0.2/N, HCl and KOH) before mixing with the agar. The medium was tubed, after boiling, in test tubes in 20 c.c. portions and sterilized.

The second culture medium, dextrose bean agar, was prepared with the addition of 1.5 per cent agar-agar in a solution containing the following: dextrose 20 grms., and lime bean decoction 1000 c.c. The lima bean decoction was prepared by boiling 200 grams of lima beans in 1000 c.c. of tap water for one hour, then straining the mixture through cheese cloth and retaining the solution.

The third, fourth, fifth and sixth were prepared by adding 5 c.c. of water or more, in the case of the sixth, in test tubes containing the vegetable medium and sterilizing.

The seventh, beef extract agar, was prepared in a similar manner as the dextrose agar medium except that dextrose was substituted by 1 per cent beef extract.

INFLUENCE OF THE SUBSTRATUM ON THE DEVELOPMENT OF CHARACTERS

Sherbakoff, Wollenweber and other investigators observed that different media influence the development of characters in *Fusaria* in a number of ways. The writer observed that certain nutrient substances different in their chemical constitution may induce development of certain characters and inhibition of others, such as sporodochia, sclerotia and pigment. In addition, the ratio between dextrose and peptone, in certain culture media, was observed to be a factor influencing sporulation (sporodochial macroconidia) versus aerial growth and vice versa. In culture media rich in dextrose sporulation was found to be abundant while development of aerial mycelium was very poor. The reverse took place, however, in culture media rich in peptone and poor or lacking entirely in dextrose. Amygdalin was

observed to induce the development of spores of approximately uniform size and septation. Colorless sclerotia and similar plectenchymatic bodies are not constant characters in the development of certain species. Such characters may appear in the culture of the initial isolation and in a few transfers but seldom reappear in later cultures. Bluish sclerotia, however, constitute a constant morphological character not affected by prolonged cultural conditions, in certain species.

DISCUSSION

The mere fact that soil is the natural habitat of *Fusaria* might be the chief reason for explaining the occurrence of such a great number of species of these organisms on onion roots. What is understood by specificity, in the case of certain *Fusarium* diseases, does not seem to apply in this particular disease. Species which have been reported by previous investigators as being pathogenic on plants such as potato, pepper, pea and tomato have also been found to occur on diseased onion roots, and in the case of *F. rhizochromatistes*, to produce pink root symptoms on two or three different plants.

These observations lead to the conclusion that the study of diseases induced by *Fusaria* present a very complicated aspect, due, on the one hand, to the specificity of certain of these organisms in regard to their host, and, on the other hand, to the non-specificity of certain others.

The writer suggests that, in a systematic study on *Fusaria*, only those nutritive substances whose chemical composition is known should be employed for the development of certain morphological characters. The results which were obtained in both solid and liquid media with dextrose and amygdalin were very satisfactory. Great confidence should not be placed on media prepared with vegetable tissues because of the variation of these tissues in their chemical composition, especially, when obtained from different sources and at different seasons.

SUMMARY

Twenty different species and varieties of *Fusarium*, some new and others already described and named, have been isolated from diseased and dead onion roots with and without symptoms of pink root disease. Some of these organisms are known to produce wilt and rot diseases on potatoes, tomatoes, peppers and certain other plants.

The new species which are reported and described in this paper are the following:

***Fusarium cromyophthoron* n. sp.,**

***Fusarium rhizochromatistes* n. sp.,**

Fusarium rhizochromatistes var. **microsclerotium** n. v.,

Fusarium sclerostromaton n. sp.,

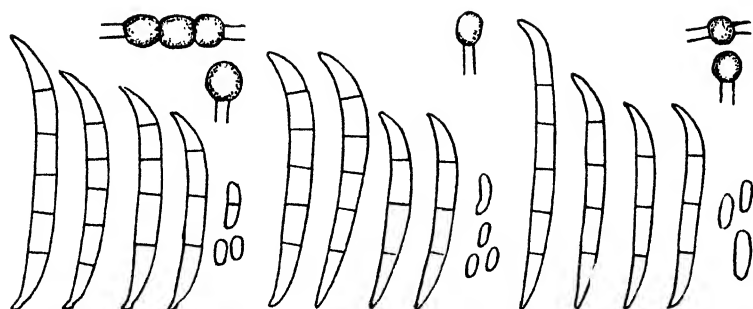
Fusarium loncheceras n. sp.

Fusarium loncheceras var. **microsporon** n. v.

The development of certain morphological characters has been observed to be influenced by the chemical nature of the substratum. Protein substances induce the development of aerial mycelium growth while at the same time decrease the rate of production of sporodochial macroconidia. The reverse, however, takes place when dextrose is used as the source of carbon in the medium.

LITERATURE CITED

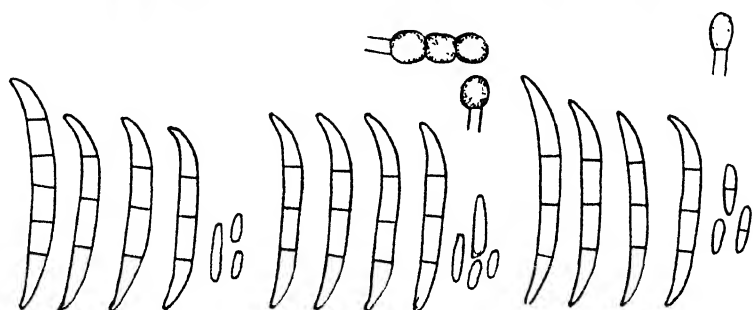
- (1) APPEL, OTTO and H. W. WOLLENWEBER. Grundlagen einer monographie der gattung *Fusarium* (Link). Arb. Biol. Anst. f. Land. u. Forstw. Bd. 8. 207 p., 10 figs., 31 pl. (1 col.). 1910.
- (2) CARPENTER, C. W. Some potato tuber-rots caused by species of *Fusarium*. Jour. Agric. Res. 5: 183-210. Pl. 14-19 and 2 col. pl. 1915. Literature cited, p. 208-209.
- (3) SHERBAKOFF, C. D. Fusaria of potatoes. Cornell Univ. Agric. Exp. Sta. Memoir 6: 87-270. 7 col. pl. 1915. Literature, p. 269-270.
- (4) ————. Fusaria of wheat and corn. Phytopath. 12: 45. 1922.
- (5) TAUBENHAUS, J. J. and MALLY, F. W. Pink root disease of onions and its control in Texas. Texas Agric. Exp. Sta. Bul. 273. 43 p. 1921.
- (6) WOLLENWEBER, H. W. Identification of species of *Fusarium* occurring on the sweet potato, *Ipomoea batatas*. Jour. Agric. Res. 2: 251-286. Pl. 12-16. 1914. Literature cited, p. 284-285.
- (7) ————. Studies on the *Fusarium* problem. Phytopath. 3: 24-50. Pl. 5. 1913.



F. oxysporum Scht.

F. mali Taub.

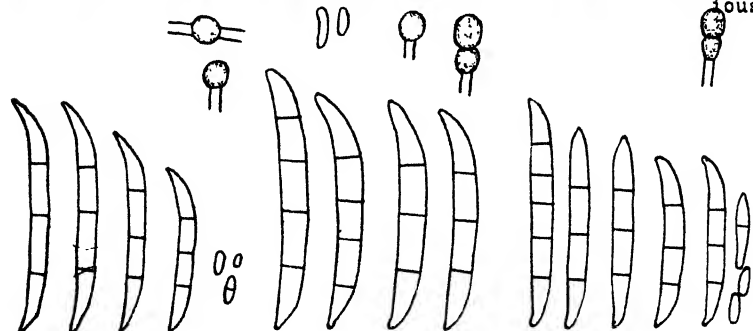
F. crenomyophthoron, n. sp.



F. redolens Wr.

F. lutulatum Sher.

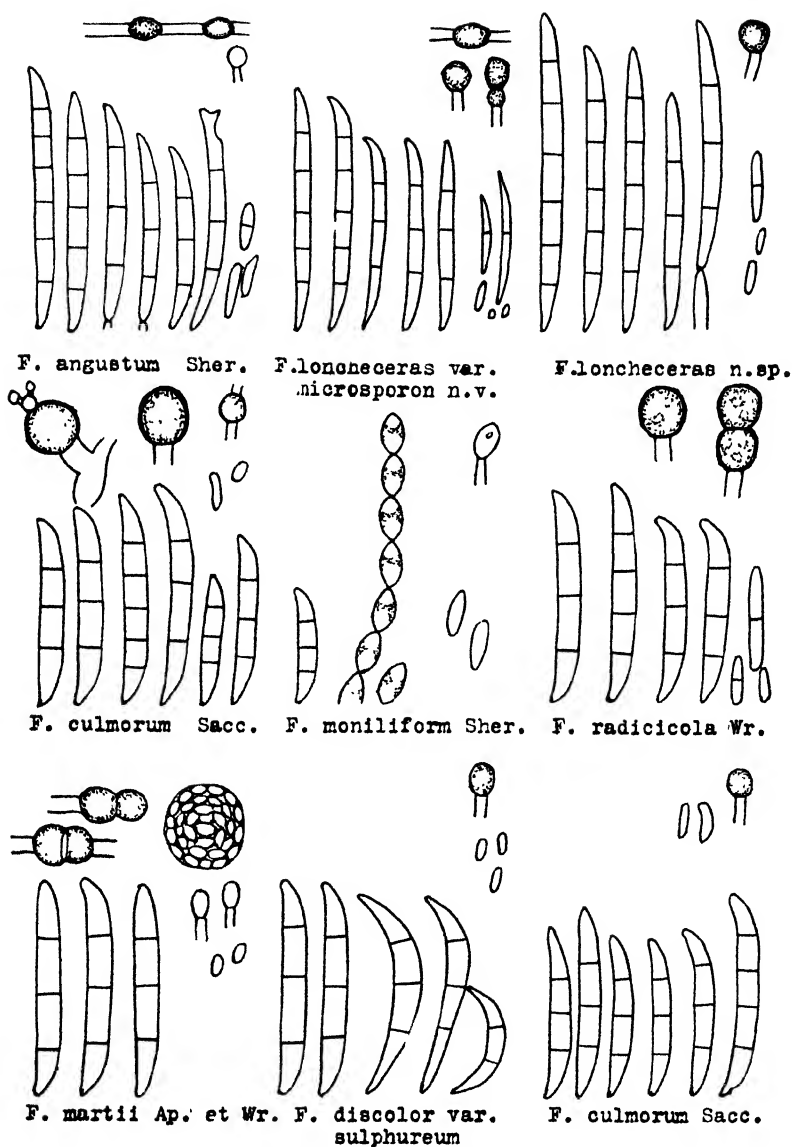
F. oxysporum var. *longius*.



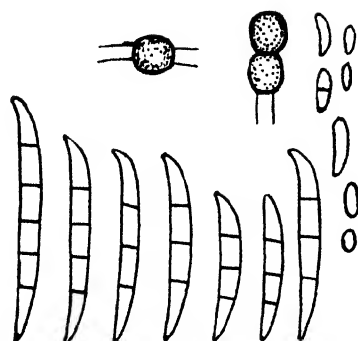
F. oxysporum var. *resupinatum* Sher.

F. discolor Ap. et Wr.

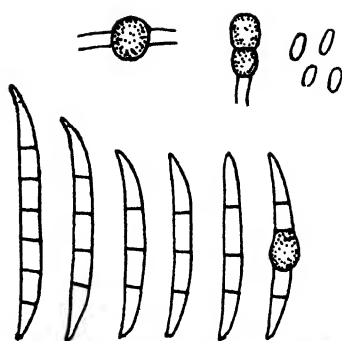
F. orthoceras var. *triseptatum* Wr.



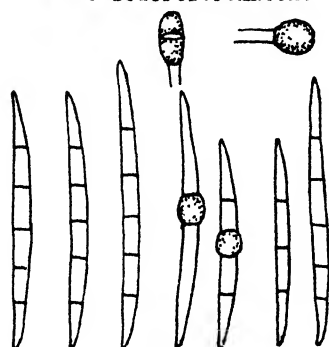
FUSARIA FROM ONION ROOTS



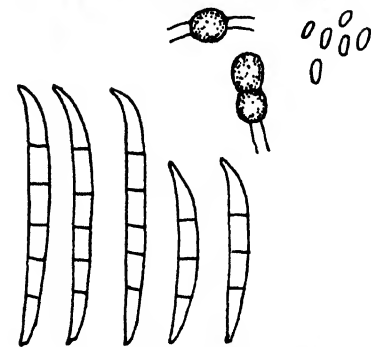
F. sclerostromaton.



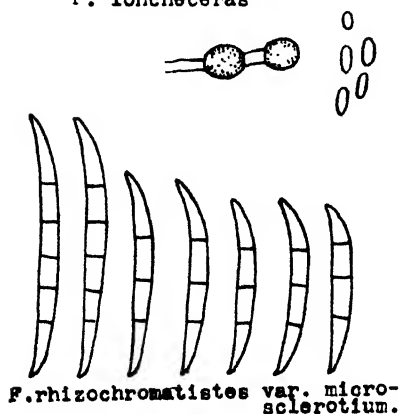
F. rhizochromatistes.



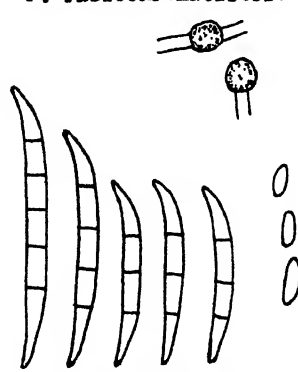
F. loncheceras



F. rhizochromatistes.



F. rhizochromatistes var. *microsclerotium.*



F. cromeophthoron.

optimum between 25° C. and 30° C. The organism in culture survives long exposures to temperatures far below 0° C. The optimum temperature for spore germination lies between 25° C. and 30° C.

Growth and the formation of pycnosclerotia in culture occur irrespective of light or darkness. Canker enlargement and the formation of pycnosclerotia may occur in the winter in Illinois during prolonged warm, moist periods; it usually begins, however, early in the spring (Plate XIII, figs. D and G) after having been suspended for the winter (Plate XIII, fig. C). The enlargement of the canker in the spring is accompanied by the formation of true pycnidia. These are also an important source of inoculum. After August only pycnosclerotia are produced on the growing cankers. These produce spores early in the following year although they are not mature until spring. New cankers appear on the new growth in August and at that time bear only pycnosclerotia (Plate XIII, fig. B). Late appearing leaf and fruit lesions, as the result of infections after July and August, bear only pycnosclerotia which either remain sterile or give rise to pycnospores in the following spring. The primary lesions on the fruit and foliage play an important part as sources of inoculum for summer infections. The pycnidia on the fruit which have already functioned during the season "fill up" and become typical pycnosclerotia² in the autumn, in which stage they pass the winter.

Natural infections occurred in Illinois during the period of these investigations as early as April and as late as September. Periods of natural infection were carefully determined by bagging experiments (Plate XII, fig. A). Primary infections began in the period between two and three weeks after the blossoms had fallen.

The cankers are probably the exclusive source of primary inoculum. The overwintering pycnosclerotia on the mummied fruit and fallen leaves give rise to pycnospores in the following spring, but the relative importance of these pycnosclerotia as sources of primary inoculum is probably negligible. Many of these overwintering pycnosclerotia become sterile.

The ascigerous stage of the organism has not been discovered although there are reasons to believe that one exists and that it occurs rarely on decaying leaves and mummied fruits in the spring, as one of the final stages of the pycnosclerotium (Plate XII, fig. D) as is the case with *Guignardia vaccinii* Shear, *G. biduelli* (E.) V. & R. and *G. acsculi* (Pk.) Stewart.

² Reddick (The Black Rot Disease of Grapes. Cornell University Agr. Exp. Sta. Bul. 293, 1911) first used the term pycnosclerotium referring to a pycnidium containing a pseudoparenchyma of large cells which gives rise to a perithecium. Since perithecia have never been observed resulting from the differentiation of the pycnosclerotium of *P. solitaria* the word is here used in a slightly different sense from that of Reddick although the form and structure of the fruit is in all respects the same.

There are three distinct types of fruit blotch, these showing differences in the histology of the affected tissues the result of varietal differences of the host rather than distinct strains of the fungus. These have been designated as the fringed, the pitted and the blistered types of apple blotch.

The fungus stimulates the host to excessive hyperplasia and to the formation of absciss layers (Plate XIII, fig. B).

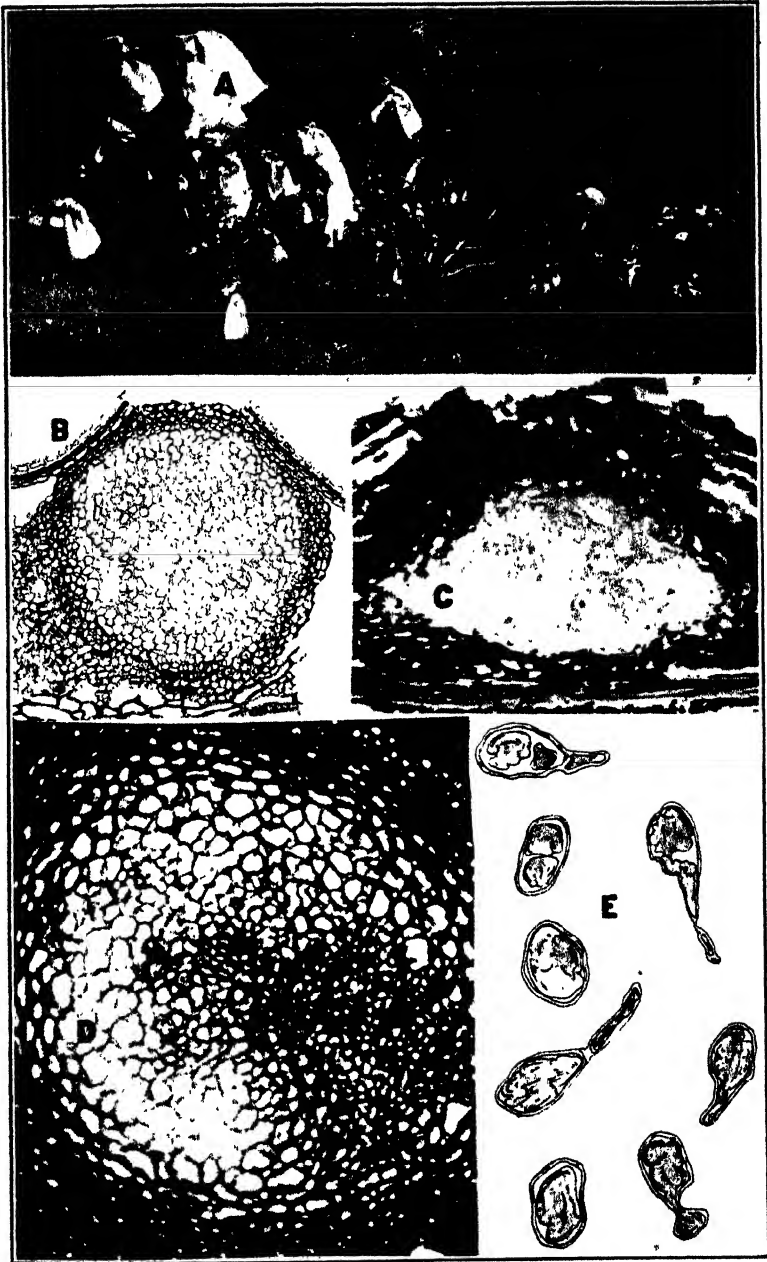
In the bark the cambium is not directly affected. Removal of the fungus by cutting away the canker may therefore be readily accomplished.

The fungus persists in the bark of some varieties indefinitely and in others natural excision occurs within three or four years. Natural excision of the cankers as one means of exterminating or suppressing the fungus as advocated in the early literature is however not dependable.

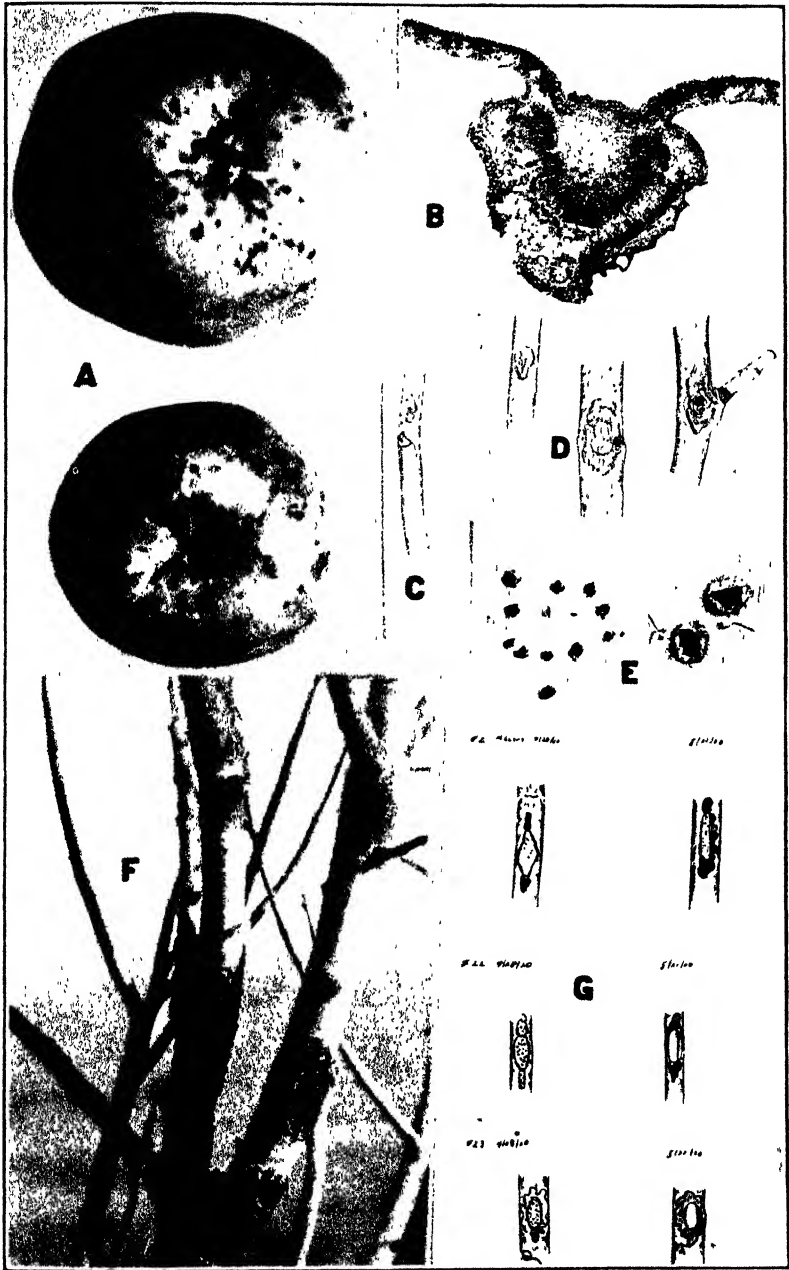
In the opinion of the writer the removal of the cankers on young trees as recommended by Gardner (1, 2) does not appear to be practicable. Other methods of control have accomplished the same end. These methods consist in the selection and planting of disease free trees, delayed dormant and summer spraying, care in the selection of varieties, avoiding near planting of bark-susceptible with bark-resistant varieties and the natural excision of cankers. Plate XIII, fig. F, shows the typical condition of young bark-susceptible varieties of apple trees in Southern Illinois orchards and Plate XIII, fig. A, the result of an ordinary infection of the fruit. Under these conditions especially canker eradication appears neither practicable, profitable or successfully possible.

The fungus may be partially controlled with late dormant sprays of lime sulfur or copper sulfate at concentrated solutions as reported previously by Guba (3, 4). The affected spores are killed and remain in the dead pycnosclerotia (Plate XII, figs. C and E).

Summer sprays of lime sulfur at two and three weeks and bordeaux mixture at four, six and ten weeks after the fall of the blossoms control the fungus perfectly, although with heavy late seasonal rains an additional spray of bordeaux mixture is necessary in August on late susceptible varieties to insure clean fruit. The first blotch spray or what is frequently termed "the 2 week spray" in southern Illinois must be on the trees not later than 2 weeks after 75 per cent of the blossoms have fallen. Lime sulfur and bordeaux mixture are equally effective as indicated by the unpublished results of the author's experiments. For Duchess and Yellow Transparent apples a 2-3-4-6 week spray schedule is recommended and for the Benoni a 2-3-4-6-8 week schedule. These applications supplement the calyx and earlier sprays, the former application also affecting control of the primary infections which in some years may occur prior to the 2 weeks application.



PHYLLOSTICTA ON APPLE



PHYLOSTICTA ON APPLE

BIBLIOGRAPHY

- (1) GARDNER, M. W., et al. Apple blotch. Purdue University Agric. Exp. Sta. Bul. 267. 32 p., 12 fig. 1923. Literature cited, p. 31-32.
- (2) GARDNER, M. W. Origin and control of apple blotch cankers. Journ. Agr. Res. 25: 403-418. 1923. Literature cited, p. 417-418.
- (3) GUBA, E. F. Effect of dormant lime sulphur upon the control of apple blotch. Science, 53: 484-485. 1921.
- (4) ———. The nature and control of apple blotch. Illinois Agriculturist, 26: 197-198, 218, 222. April, 1922.
- (5) HÖHNEL, FRANZ VON. Mykologische Fragmente. Ann. Myc. 18: 71-97. p. 93-95. 1920.
- (6) SHEAR, C. L. Life histories and undescribed genera and species of fungi. Mycologia, 15: 120-131. 7 fig., pl. 12-13. 1923.
- (7) SYDOW, H. & P., and E. J. BUTLER. *Fungi Induc orientalis*. (Pars V.) Ann. Myc. 14: 177-220. 4 figs. 1916.

EXPLANATION OF PLATES

PLATE XII. Fig. A. Fruit and leaves protected against natural infection in a Duchess orchard. Bagging experiments to determine periods of inoculation. Fig. B. Section through a pycnosclerotium from a canker in December. Fig. C. Section through a pycnosclerotium treated with a late dormant spray of lime sulfur. Fig. D. Section through a pycnosclerotium from a fallen mummied apple in January. Fig. E. Spores from a pycnosclerotium from a canker treated with lime sulfur late in the dormant season.

PLATE XIII. Fig. A. Yellow Transparent apples showing the result of an ordinary infection in Southern Illinois. Fig. B. Section through the midvein of a leaf showing the canker, the absciss layer and the underlying hyperplasia. Fig. C. A canker during the dormant season. This canker resulted from an infection during the previous growing season. Fig. D. Cankers showing the intermittent areas of growth. Fig. E. Exposed pycnosclerotia in the cankers. Fig. F. A 4-year-old Duchess tree, a typical example of young susceptible apple stock in Southern Illinois. Fig. G. Showing the enlargement of the cankers following the dormant season of the host.

THE PRODUCTION OF SUBSTANCES TOXIC TO PLANTS BY PENICILLIUM EXPANSUM LINK

CLYDE C. BAENUM

WITH TWO FIGURES IN THE TEXT

The toxic action of culture solutions on which *Penicillium expansum* Link had been grown was first observed by the writer in the spring of 1923. At this time, cut stems of vetch (*Vicia gigantea* Hook.) and mint (*Mentha sp.*) were placed with the cut ends of the stems in culture solutions on which the fungus had grown in pure culture, as well as in fresh sterile culture solutions and in equal volumes of tap water. After 24 hours the leaves and stems in the solution on which the fungus had grown were decidedly wilted and in 36 hours the leaves were dry and brittle. The controls in the uninoculated culture solution and in the tap water were fresh and in a growing condition after 48 hours. These results, although not checked up at that time by further work, led the writer to believe that some toxic principle was involved which must have been produced in the culture solution by the fungus. Since no mycelium was present in the solutions used, it was hardly conceivable that the wilting induced by their use was attributable to a choking of the vascular system. This toxicity, induced by a fungus which is commonly known as a strict saprophyte, is similar in many ways to the toxic principle attributed to pathogens, such as *Fusaria*.

Fahmy (1) points out that *Fusarium solani* (Mart.) Sacc. produced an excretory principle in Richard's culture solution which proved toxic to broad bean plants three weeks old. This principle was found to increase in toxicity with age, and to be thermostable and non-volatile. Fahmy also shows that the injury is not due to the small amounts of ammonium or oxalate ions produced by the organism in pure culture. Haskell (2) reports the presence of a toxic principle in the culture solutions on which *Fusarium oxysporum* Schlecht., the cause of potato wilt, had been grown. Injections of these toxic solutions into the stems of healthy potato plants produced definite browning of the vascular tissues and blackening of the leaves.

Later in 1923 further work on the study of the toxic principle produced by *P. expansum* in culture solutions was carried out by the author. Cultures were available at this time on which *P. expansum* had been grown for 9 weeks. Six of these cultures were chosen for the test on growing plant parts. Each culture had grown on 100 c.c. of Czapek's nutrient solution in 250 c.c. Erlenmeyer flasks, a different sugar having been supplied in each case. The six cultures thus represented the growth of *P. expansum* on each of the following carbohydrates: laevulose, lactose, maltose, mannite, pectin

and dextrose. The original concentration of these sugars was 3 per cent in each case. The mycelial felt in each flask was pushed aside sufficiently to allow the insertion of freshly cut ends of terminal leafy stems of *Malva rotundifolia* L. into the culture solution without the cut ends coming in contact with the spores. Controls, consisting of 100 c.c. lots of freshly prepared Czapek's solution containing 3½ per cent dextrose were used and cut stems of the same plants were placed in these with the cut ends immersed in the solution. Tap water controls were also prepared and stems placed in them at the same time. After 18 hours all the branches in the 6 cultures were definitely wilted. (See figure 1.) Wilting was apparent within one hour after the stems were placed in the cultures. After 48 hours the same stems were completely withered and the leaves were dry and brittle. The controls, both in the fresh, sterile solutions and in tap water were fresh and growing at the tips at the conclusion of the experiment.



FIG. 1. Stems of *Malva rotundifolia* in Czapek's solution 20 hours. On left, stems wilted in solutions on which *P. expansum* had grown 9 weeks. On right, stems in solutions on which no fungus had been grown.

This study indicates that the fungus, *P. expansum*, produces in culture solution a toxic principle which is capable of causing wilting of cut stems of common *Malva* when placed in such solutions. A study of longitudinal sections of these wilted stems showed that the stain of the culture solution on which the fungus had grown had been carried up into the stems of the wilted plants a distance of 5 to 7 inches. *P. expansum* changes the color of the medium from an original clear liquor to a definitely dark amber color. The appearance of the stain in the tissues of the leafy plants some distance from the cut ends indicates that there had been no interference with the water conduction of the stem.

TOXICITY IN RELATION TO CAULIFLOWER PLANTS

In order to check up on the previous work, three liters of Czapek's modified nutrient solution were prepared according to the usual formula, adding 3½ per cent of dextrose in all cases. The stock was divided into the following portions, and autoclaved 10 minutes at 15 lbs. pressure:

9-200 c.c. lots at pH 4.4 in 500 c.c. flasks

5-100 c.c. lots at pH 4.4 in 250 c.c. flasks

5-100 c.c. lots at pH 7.0 in 250 c.c. flasks

Spores from pure cultures of *P. expansum* were planted on the 9-200 c.c. lots and the cultures incubated at room temperature (15-20° C.). Good growth resulted and the mats were strong and covered with green spores after the third day. After 16 days the solutions were decanted from the flasks and filtered by suction through a Buchner funnel, using double layers of filter paper and a heavy mass of absorbent cotton, previously moistened with distilled water. Careful microscopic observation of the filtrate indicated the absence of spores. This filtrate will be referred to in this paper as the "cultured" solution. Volumes of 100 c.c. of the "cultured" solu-



FIG. 2. Cauliflower plants in Czapek's solution for 68 hours. Numbers on flasks correspond to the numbers given the various solutions in table 1.

tion, the sterile solutions at different H-ion concentrations, tap water and distilled water were placed in 250 c.c. Erlenmeyer flasks and identified by number as shown in table 1.

TABLE 1.—*Solutions used in toxicity tests on cauliflower plants.*

No.	Condition of solution	No. & vol. in flasks 2-100 c.c.	No. plants used
1	Cultured soln. filtered, unheated, pH 5.0	"	2
2	Cultured soln. filtered, heated to boiling	"	3
3	Cultured soln. filtered, autoclaved 15 minutes	"	2
4	Cultured soln. filtered, unheated, plus toluol	"	2
5	Cultured soln. not heated, not filtered	"	2
6	Cultured soln. filtered, plus 1 c.c. N NaOH per 100 c.c. sol.	"	2
7	Cultured soln. filtered, plus 1 c.c. N/2 HCl per 100 c.c. sol.	"	2
8	Sterile Czapek soln. pH 4.4 no growth, no toluol	"	2
9	Sterile Czapek soln. pH 7.0 no growth, no toluol	"	2
10	Sterile Czapek soln. pH 4.4 no growth, toluol added	"	4
11	Sterile Czapek soln. pH 7.0 no growth, toluol added	"	4
12	Tap water, autoclaved, plus toluol	"	3
13	Tap water, unheated, no toluol	"	4
14	Tap water, boiled, no toluol	"	4
15	Distilled water, plus toluol	"	4
16	Distilled water, no toluol	"	4
17	150 c.c. "cultured" soln. filtered, plus 50 c.c. Dist. Water	"	4
18	Plants in dry flasks	2	5

Due to a scarcity of herbaceous plant material at this time, young cauliflower plants (*Brassica oleracea* var. *Botrytis*) grown 3 months in the open ground and not over 6 to 8 inches in height, were used in this experiment. The plants were pulled, washed free of soil and placed within 10 minutes after their removal from the soil in the flasks as indicated in table 1. After 18 hours the injurious effect of the toxic solutions was noted in a definite wilting of the plants which had their roots bathed in these cultured solutions. The presence of broken roots was negligible on account of soil conditions and care in pulling plants. Less toxicity was noted in the first 24 hours in the solution which had been autoclaved after the fungus had grown on it, but this delayed action was just as effective in producing wilting in the latter part of the experiment as was the more rapid action of the unheated "cultured" solution. (See figure 2.)

In the boiled "cultured" solution there was scarcely any less injury to the plants during the first few hours than in the unboiled "cultured" solution. However, the wilting was finally equally as pronounced in these two solutions and the leaves of all the plants were much drier and more brittle than the leaves on the plants in dry Erlenmeyer flasks. The use of toluol was found to be unnecessary during these tests of short duration, the injurious effects on the tissues of the plants were found to more than offset any value in maintaining a condition of sterility in the solutions under test. All the plants kept in the various control solutions were in a growing condition at the conclusion of the experiment after 68 hours. (See table 2.)

TOXICITY IN RELATION TO GROWING ALFALFA STEMS

Growing stems of alfalfa, *Medicago sativa* L. were placed in some of the same test solutions used in the foregoing test, in the order shown in table 3.

TABLE 2.—*Condition of cauliflower plants at different times during toxicity tests.*

No. of Solution	After 18 hours	After 22 hours	After 43 hours	After 68 hours
1	Wilting	Wilting definite	Leaves dry	Leaves brittle
2	Slight wilting	Wilting definite	Leaves dry	Leaves brittle
3	No wilting	No wilting	Leaves limp	Leaves limp
4	Slight wilting	Wilting definite	Leaves dry	Leaves dry
5	Wilting	Wilting	Leaves dry & yellow	Leaves dry
6	Wilting	Wilting	Leaves limp	Leaves limp
7	Wilting	Wilting	Wilting definite	Leaves dry
8	No wilting	No wilting	No wilting	Plants growing
9	1 plant wilted 1 plant growing	1 wilted 1 growing	Plants recovered	Plants growing
10	No wilting	No wilting	No wilting	Plants growing
11	No wilting	No wilting	No wilting	Plants growing
12	No wilting	No wilting	No wilting	Plants growing
13	No wilting	No wilting	No wilting	Plants growing
14	No wilting	No wilting	No wilting	Plants growing
15	No wilting	No wilting	No wilting	Plants growing
16	No wilting	No wilting	No wilting	Plants growing
17	Wilting definite	Wilting definite	Wilted badly	Leaves dry
18	Wilting definite	Wilting definite	Wilted badly	Leaves dry, not brittle

X

TABLE 3.—*Solutions used in toxicity tests on alfalfa stems.*

No.	Condition of solution	No. & vol. in flasks	No. plants used
1	"Cultured" soln. filtered, unheated pH 5.0	2-100 c.c.	2
2	"Cultured" soln. filtered, boiled 1 min.	2-100 c.c.	3
3	"Cultured" soln. filtered, autoclaved 15 min.	2-100 c.c.	2
5	"Cultured" soln. not filtered, not heated	2-100 c.c.	2
6	"Cultured" soln. filtered, plus 1 c.c. N NaOH	2-100 c.c.	2
7	"Cultured" soln. filtered, plus 1 c.c. N/2 HCl	2-100 c.c.	2
8	Sterile fresh culture soln. pH 4.40	2-100 c.c.	2
9	Sterile fresh culture soln. pH 7.00	2-100 c.c.	2
13	Cold tap water	2-100 c.c.	2
14	Autoclaved tap water	2-100 c.c.	2
16	Distilled water	2-100 c.c.	2
17	150 c.c. "cultured" soln. plus 50 c.c. water	2-100 c.c.	4
18	No solution in flasks, air dry	2	5

After 2 hours in these test solutions, wilting was apparent in sets numbered 1, 2, 3, 5, 6, 17 and 18 in equal amounts in all cases. After 20 hours the same conditions existed, except that the greatest amount of wilting had occurred in No. 3 and in one plant in No. 2. After 48 hours at room temperature, the wilting had progressed in all the "cultured" solutions, both boiled and autoclaved, acid and alkali treated and diluted, to such an extent that the leaves on the stems were dried entirely and were more brittle than those on the stems in the empty flasks without water. After 4 days time all stems were dry except those in the sterile fresh culture solution.

The results of these experiments indicate that a toxic principle is produced in the culture solution upon which *P. expansum* has grown, and that this product of fungus growth is capable of causing wilting in certain herbaceous plants, whether absorbed through the cut ends of the stem or through the roots of the growing plants. This principle has proved to be thermostable and non-volatile, as was determined by Fahmy for the toxic principle produced by *F. solani*.

This work indicates that the production of a wilt-inducing principle in culture solutions is not limited to plant pathogens such as *Fusarium sp.*, but that a saprophytic fungus like *Penicillium* may act in a similar manner.

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REFERENCES CITED

- ✓ (1) FAHMY, T. The production by *Fusarium solani* of a toxic excretory substance capable of causing wilting in plants. *Phytopathology* 13: 543-550. Dec., 1923.
(2) HASKELL, R. J. *Fusarium* wilt of potato in the Hudson River Valley, New York. *Phytopathology* 9: 223-260. June, 1919. Literature cited, p. 259-260.

PHYTOPATHOLOGICAL NOTES

Infection produced by the spores of Ustilago striaeformis (Westd.) Niessl.—The writer has experienced difficulty in infecting timothy with germinated spores of *Ustilago striaeformis* from timothy. Preliminary results point to seedling infection as a good percentage in one lot of inoculated plantlets show infection after three months while the checks are not infected. Investigations are now under way to verify this preliminary experiment and complete the problem.—W. H. DAVIS.

National Southeastern University of Nanking, China.—On the 12th of December, 1923, the main building of the College of Agriculture of the National Southeastern University of Nanking, China, was destroyed by fire. Practically all of their library dealing with the Entomology and Plant Pathology was destroyed. The work in Plant Pathology was just getting well under way in this Institution. This disaster will greatly handicap the work there. An appeal has been made to me by Professor F. L. Tai, of the Department of Plant Pathology, and by Professor G. P. Jung, of the Department of Entomology, asking for the assistance of their American colleagues in the matter of reprints, bulletins, etc., dealing with Plant Pathology and Entomology. I trust that the members of the American Phytopathological Society will each contribute whatever they can from their publications. Contributions should be mailed to either of the above-named professors or to Professor P. W. Tsou, Dean of the College of Agriculture there.—H. H. WHETZEL.

Honors for Dr. A. Jaczewski.—The Mycological section of the Russian Botanical Society, the permanent Board of the Entomo-Phytopathological Congresses and the State Institute of Experimental Agronomy announce that on February 27, 1924, at 1 p. m. in the rooms of the Hale Institute of Experimental Agronomy (Petrograd, Morskaia street, 42) was celebrated the thirty-fifth anniversary of the scientific activity of Professor A. Jaczewski. The order of the day consisted in the reading of telegrams and congratulations and in the offering of a special medal for remembrance of this day of anniversary.

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PHYTOPATHOLOGY

VOLUME XIV

NUMBER 6

JUNE, 1924

SPORE GERMINATION OF *USTILAGO STRIAEFORMIS*

WILLIAM HAROLD DAVIS¹

WITH PLATES XIV-XVI AND ONE TEXT FIGURE

During each decade of the last half century, some scientific investigator has endeavored to germinate the smut spores of *Ustilago striaeformis* (Westd.) Niessl which parasitizes some of our most important economic grasses. Published observations of these investigators show that conditions for the successful germination of the smut spores of this fungus have not been understood and, for this reason, there has been more or less speculation as to whether the organism is an *Ustilago* or a *Tilletia*. Furthermore, in later years, mycologists and pathologists have assigned the smut organisms on our common grasses to one morphological species of *Ustilago*, *U. striaeformis*, regardless of the grass host parasitized. This was probably due to the fact that the symptoms of the disease and the sizes and echinulated surfaces of the spores are comparatively the same on each of the different grass hosts. Even if there is only one morphological species, the problem of physiological races and the life history of the organism cannot be solved until the conditions for the germination of the spores have been definitely determined.

This investigation was undertaken for the specific purpose of determining the natural conditions under which the spores of this smut germinate, the nature of the germination, the genus of the fungus on each host investigated.

THE DISEASE

The leaf smut of timothy appears on the leaves and stems of grasses as long, narrow, dark striations which split open and shred the leaf blades into long strips. (Plate XIV, fig. 1.) The writer has observed these striations on rachides, rachillae, glumes, lemmata, palea, stamens and ovaries of timothy and redtop plants. Ovaries of timothy and redtop are sometimes filled with spore masses similar to smutted ovaries in the closed smuts of cereals.

¹ The writer wishes to express sincere appreciation to Professor L. R. Jones for his inspiration and assistance during this investigation and in the preparation of the manuscript; to Dr. J. J. Davis and Dr. J. G. Dickson for suggestions and criticisms.

(Plate XIV, figs. 2, 3, 4 A-B.) Also, there is a noticeable dwarfing of the diseased culms which average about six tenths of the height of healthy ones. Diseased culms seldom bear seeds but when they do, the yield is about one fourth the number commonly observed on healthy plants.

The striations and smutted ovaries are filled with spores,² the surfaces of which are covered with a thin, hyaline wrinkled membranous tissue appearing microscopically as a fine network. In this network are spines or aciculae less than one micron in length and from thirty to seventy on one facies of a spore. Underneath the network is a rather thick colored layer, the exosporium, which covers a thicker, hyaline layer, the endosporium. No germ-spores were observed in the spore walls. (Plate XIV, fig. 4, F-G.)

The measurements of 50 fresh smut spores removed from dried leaves of different hosts and mounted in water follow:

Timothy	8.4 × 11	microns
Redtop	9.3 × 11.1	“
June grass	8.6 × 10.2	“
Orchard grass	10.7 × 11.5	“

Limits for all four hosts, 8-11 × 10-12 microns.

The writer has collected *U. striaeformis* on the following hosts: redtop, *Agrostis palustris* Huds.; timothy, *Phleum pratense* L.; June grass, *Poa pratensis* L.; orchard grass, *Dactylis glomerata* L. Although this smut has been reported as a parasite on about 40 different species of the Gramineae, this investigation deals with the smut found on timothy, redtop, June and orchard grasses only. An examination of reports from various countries and states would lead one to believe that the disease is principally confined to the humid central portion of the north temperate zone between the north parallels of 30 and 50 degrees. Different reports of losses within this area vary. Clinton (7) cited an instance where the seed production was reduced from 30 cwt. to 70 cwt. In 1905, he reported the parasite especially harmful to lawn grass which observations confirmed Pammel's of 1893-1901. Osner (19) found the loss as high as 30 per cent, while Johnson and Haskell (16) reported a slight loss in Minnesota, Wisconsin, Idaho, and a trace in Iowa. The writer's observations verify the above reports. The most critical period for infected plants occurred during periods of drought when over 90 per cent of the infected plants succumbed. Thus most of the losses may be placed in four classes: (1) reduction in yield of hay as indicated by shredding of diseased leaves; (2) reduction in amount and quality of seed; (3) lowering the carrying capacity of pastures; (4) injury to lawns.

² In conformity with common usage, the term smut "spore" is here used synonymously for chlamydospore.

METHODS

Spore germination tests were made of smutted materials from timothy, redtop, June and orchard grass and then portions of each of these materials were placed in wire packets stored outdoors. The remaining portions were placed in corked vials lined with wet filter paper and stored in the laboratory. In addition, some infected plants were marked in the field; others removed from the field, transplanted into pots and grown in the greenhouse.

The mycelium in all host tissues was well differentiated by staining with Flemming's safranin-gentian-violet-orange G., employing a 120:2:1 minute staining schedule. The germinated spores were stained according to a method described by the author (11).

The agars, solutions and decoctions were prepared according to formulae described by Duggar, Jensen (15), Guillermond and Tanner (13).

The percentage of spore germination was obtained by counting 100 spores in an average field under the 8 mm. objective and, at the same time, recording the number germinated. The average germination obtained from a number of such counts was recorded as the percentage of germination for the sample.

GERMINATION OF FRESH SPORES

Brefeld (3, 5) showed that some smut spores which germinate sparsely or not at all in water, germinate and sporulate satisfactorily when incubated in nutrient solution. In an endeavor to find a medium suitable for germination, smut spores from timothy, redtop, June and orchard grass were incubated in various solutions and on different substrata under different conditions of air, heat, light and moisture. The spores were removed from infected green leaves, from infected leaves in the bud not yet unrolled and from old dried leaves growing in the field and in the greenhouse.

A list of materials employed follows: sterilized, unsterilized and filtered water from melted snow, from a tap and from a cistern; juices of potato tuber; rhubarb petioles, cherry, apple, grape, pear, peach, lemon, orange, tomato, plum and prune; decoctions prepared from different parts of the grass hosts (roots, culm, leaf, blossom and seedling), prunes, raisins and manures; water solutions of nectar from the Easter lily, aphid "honey dew," honey, molasses, renin, pepsin, trypsin, saliva, vitamin B, ammonia and wine; nutrient solutions such as Cohn's, Pasteur's, Laurent's, beerwort, beef broth; agars as prune, potato dextrose, potato, corn meal, oat, water and beerwort; substrata composed of plant parts as roots, stems, leaves, flowers, seeds, seedlings and decayed parts of the hosts; also on damp filter paper and pith laid on acid, alkaline and neutral soils and submerged in the soil water; solutions of acids such as oxalic, malic, citric, tartaric, sulphuric, nitric and hydrochloric.

In fifty spore germination tests with water from different sources, less than ten germinated spores from timothy were observed and those in two cultures. Four repeated trials with the solutions apparently favorable in the first trial, showed the smut spores from June grass germinated less than 0.5 per cent in the decoctions but germinated spores were also found in the distilled water checks. Smut spores from June grass also germinated in a 0.2 per cent citric and malic acid solutions adjusted to +15 and +20 Fuller's scale. However, a repetition of this experiment employing two-months'-old spores from timothy gave good spore germination from +5 to +16. This test together with others showed that the age of the spore influenced the results and was a greater factor in germination than the acidity of the solution employed.

Thus it would seem that favorable germination of fresh smut spores from timothy, redtop, June and orchard grasses is not entirely dependent on any one of the following factors: (1) age of the infected *green leaf* from which the spores may be removed; (2) the kind of solution, decoction, plant part or other substrate on which the spores are placed; (3) intermittent freezing and thawing; a certain temperature or varying amounts of air and moisture.

SPORE DISINFECTION

The surfaces of after-ripened spores from timothy and orchard grass were sterilized in a four per cent and a one per cent copper sulfate solution, a 1:1000 mercuric bichloride solution and sterile distilled water acting for intervals varying from one to fifteen minutes. The spores were separated from the liquids by methods commonly used for such work employing a centrifuge and the necessary aseptic precautions. After sterilizing and centrifuging, the spore samples were transferred to Cohn's, Laurent's and Pasteur's solutions with and without a five per cent molasses solution; beerwort, manure extract, a 10 per cent strained honey solution, sterile water; to agars as potato, nutrient, onion, beerwort, oat and Czapek's. The H-ion concentration of Czapek's agar was varied as follows: pH 4.2, 4.8, 5, 6, 6.2, 7.1, 8.4.

The results showed that either a four per cent or a one per cent copper sulfate solution acting on the after-ripened spores from timothy and orchard grass for five minutes prevented germination. A few spores germinated after being treated for three minutes in the copper sulfate solutions but the spore surfaces were not always sterilized. In no case did the treated spores germinate over five per cent, while the checks germinated 50 to 90 per cent.

Spores treated two minutes in the mercuric bichloride solution failed to germinate while the untreated checks germinated 30 to 90 per cent. This

solution like the copper sulfate solution proved unsatisfactory because a sufficient number of the spores did not remain viable after the briefest period for which the spores could be conveniently treated.

Cohn's, Pasteur's and Laurent's nutrient solutions, manure decoctions and beerwort did not cause abundant formation of typical sporidia. The promycelium grew and branched in the honey solution but typical sporidia failed to develop.

On agars, a few promycelia grew in length about twice the spore diameter, after which growth ceased. Several promycelia branched but failed to form actively growing saprophytic mycelium during the 60 days they were under observation. Oat agar gave the best results as the promycelia were slightly longer. Varying the pH value of Czapek's agar seemed to have no beneficial effects on the growth in length of the promycelium and formation of typical sporidia.

AFTER-RIPENING AND GERMINATION

Brefeld (4), Paravicini (27), Kniep (17), Anderson (1) and Bauch (2) recognized the importance of an after-ripening or a rest period for smut spores previous to their spore germination and infection experiments. Fischer von Waldheim, Pammel, Clinton, Osner and others failed to successfully germinate the spores of *U. striaeformis* even when collected from materials of different ages. Osner (19) endeavored to find an after-ripening period for these smut spores by placing smutted portions of timothy between wire screens which were then stored outdoors. However, he was unsuccessful in germinating spores from his stored materials. Thus it can be stated that no after-ripening period for the spores of *U. striaeformis* has been observed and described.

For the purpose of finding whether the spores of *U. striaeformis* have an after-ripening period which might have been overlooked by the previous investigators, highly infected green leaves were collected from timothy, redtop, June and orchard grass growing in the field. Samples of each of these collections were stored in the laboratory and outdoors as previously described. Weekly spore germination tests were made from each sample of stored materials which represented collections made during different months of the year as those from timothy were collected and stored during the months of February, April, June, July, August and October. All data for each stored spore sample was tabulated but lack of space prohibits the presentation of this tabulation showing the name of the host, where the materials were stored, date when the spores were placed to incubate, date and per cent of maximum germination, after-ripening period in days, date for the cessation of germination and period of spore viability. However, a summary of these observations is to be found in table 1.

TABLE 1—A summary of spore germination tests showing the periods of after-ripening,¹ viability,² and germinability³ for the smut spores of *U. striaeformis*

Grass hosts	After-ripening conditions	Average after-ripening periods Days	Average periods of		No. of samples
			viability Days	germinability Days	
Timothy	Laboratory	206	287	70	5
	Outdoor	302	341	72	5
Redtop	Laboratory	302	347	71	6
	Outdoor	250	303	84	2
June	Laboratory	197	341	120	3
	Outdoor	250	325	117	3
Orchard	Laboratory	251	306	70	3
	Outdoor	254	319	64	3

¹ The after-ripening period is used synonymously with rest period, and dormant period. This period has usually been considered as the interval elapsing between spore formation and spore germination, but as the time of spore formation could not be accurately determined, the after-ripening period has been considered here as the interval which elapsed between the death of the green host tissues in which the spores were formed and the date of a test showing the maximum percentage of germination. The host tissues were considered dead on the same day as removed from the plant and stored.

² Period of viability: The period of after-ripening and the period of germinability of the smut spores—longevity of the spores.

³ Period of germinability: Elapse of time from the after-ripening period to the natural death of ungerminated smut spores.

From table 1 it is to be noted that the spores of *U. striaeformis* from timothy, redtop, June and orchard grass germinated satisfactorily after passing through an after-ripening period of approximately 250 days. Experiments showed that the after-ripening period for the spores in green materials stored in the spring was longer than for similar materials stored in the fall. Also, the after-ripening period was shorter for spores in dead materials than for those in green materials stored at the same time and under similar conditions. Thus after-ripening begins with the spores in the host. One lot of spores collected on July 3, from timothy and redtop, germinated 30 per cent but after storing for 28 days, 90 per cent. So by chance, during the summer, one might find in dead, overwintered leaves spores which are after-ripened and germinable.

Five different samples of smutted materials from each of three hosts were subjected to the fumes of chloroform for one minute then submerged in a 10 per cent citric acid solution for five minutes, washed and set to after-ripen. This treatment decreased the after-ripening period of spores from timothy about thirty days; from redtop, 18 days, and from June grass, 20 days. However, the period of after-ripening following this treat-

ment depended somewhat on the temperature at which the spores were stored, about 20° C. being the most favorable. One lot of treated spores stored at 8.5° C. after-ripened after 332 days; a second lot at 16° C. after 200 days and a third lot at 19.2° C. after 186 days, while other lots set at 5° and 30° C. failed to show after-ripening. Spores in the untreated checks also failed to after-ripen at 5° and 30° C.

The average period of viability for the smut spores from all four hosts was 320 days. However, one lot of spores in green leaves of redtop remained viable in storage for 460 days, the maximum period observed. The minimum period of viability was 124 days and this was for spores in a sample of old smutted timothy leaves collected in March and stored in the laboratory. These spores had been formed no later than during November of the previous year or 150 days previous to storage thus giving a viability of about 300 days or nearer the average, 320 days.

When the smut spores were once after-ripened and stored in a humid atmosphere at 20° C. they retained their germinability for approximately 75 days except the spores from June grass which retained germinability for 120 days. This period of germinability was difficult to ascertain with absolute certainty as each test was made with a separate lot of spores and various lots were under different conditions even in the same leaf. Observations showed that the period of germinability for smut spores formed in the fall was the same as for those formed in the spring. However, Bauch (2, p. 245) observed that the spores of *U. longissima* retained their germinability about 120 days but spores formed in the fall remained viable longer than those formed in the spring.

Thus the period of germinability for the spores from timothy, redtop and orchard grass was approximately 75 days and for smut spores from June grass, approximately 120 days.

Experiments were conducted to determine the effects of air-drying on the periods of viability and germinability. Smutted timothy plants in herbarium materials which had been stored for 1 to 20 years were stored for the spores to after-ripen. The results showed that materials thus dried in herbarium packets for one year or more were non-viable. One lot of smut spores from timothy remained viable under dry-air conditions for 140 days and a lot from redtop, 67 days. These were the maximum periods observed for spores from these hosts. If after-ripened spores were air-dried, they ceased germination, and thus their period of germinability was shortened. While, after-ripening, the spores from all four hosts seemed to withstand arid outdoor conditions fairly well but when after-ripened they quickly succumbed to similar arid conditions.

Observations of conditions for germinating spores of *U. striaeformis* removed from all four hosts seemed to warrant the following statements:

1. Spores from different pustules within a leaf vary in the time of germination and length of viability.

2. If old diseased leaves and green diseased leaves are placed under proper conditions for spore after-ripening the spores in the old leaves after-ripen and germinate first.

3. Smut spores in leaves overwintered at the base of a culm after-ripen sooner than spores removed from green leaves on the same plant collected in the following spring or summer.

4. Spores from the base of a leaf sometimes germinate before those from the tip.

5. Storage in a moist atmosphere favors after-ripening.

6. Alternate drying and moistening the materials in the early periods of after-ripening seems favorable to after-ripening.

7. Drying after-ripened spores for a period longer than seven days greatly decreased the viability, while drying them one to two days stimulated germination in three cases.

8. Smut spores from infected timothy stored in herbarium packets for 140 days and from redtop 67 days, then set to after-ripen, germinated 40 per cent showing that drying spores soon after spore formation does not impair or diminish the viability as much as drying them during the after-ripening period.

9. Low temperatures delay after-ripening; 20° C. being the most favorable.

10. Contaminations in spore germination cultures are generally unfavorable to germination. After-ripened, viable spores germinate well when on the surface and when submerged in water; also, when within decayed host tissues and "spore balls."

11. Fresh smut spores treated with chloroform and citric acid after-ripen and germinate three to four weeks earlier than untreated checks.

12. The approximate periods associated with the germination of the smut spores from timothy, redtop, June and orchard grass were observed as follows: after-ripening, 250 days; viability, 325 days; germinability, 75 days, except June grass with a germinability of 120 days.

MORPHOLOGICAL FEATURES OF GERMINATING SPORES FROM TIMOTHY, REDTOP, JUNE AND ORCHARD GRASSES

Pammel (26) stated that the spores of *Tilletia striaeformis* (Westd.) Magnus (*T. striaeformis*) germinated readily and in the same way as those of the stinking smut of wheat, *Tilletia foetens* (B. and C.) Trel., but Clinton found the spores germinated with difficulty and the promycelia of germinated spores from redtop bore cross-walls as those in the genus *Ustilago*.

Osner (19) reported cross-walls and "well developed clamp connections" in the promycelia on two slides where a few spores from redtop germinated. A review of the publications by previous investigators shows there remains some doubt regarding the type of germination of the spores of *U. striaeformis* on timothy, redtop, June and orchard grasses.

Germinating spores from timothy (Plate XV).—After properly incubating after-ripened smut spores from timothy for 12 hours, rifts appear in the exosporium (Plate XIV, Fig. 4, F) and later a hyaline germtube, the promycelium, emerges. Promycelia were two to six microns in diameter, of varying lengths from 30 microns to one millimeter when submerged in liquids and filled with granular, vacuolate, deeply staining protoplasm. The wall of the promycelium is hyaline and continuous with the spore membrane.

After 24 to 48 hours incubation, the granular protoplasm advances and assembles in the tip of the promycelium leaving a hyaline portion between it and the spore. Slides bearing stained spores which had been incubated 48 to 72 hours showed the promycelium bears cross-walls and one to five branches or lateral sporidia which generally appear near the cross-walls on the side towards the spore. The cross-walls, number and length of lateral sporidia were aided by the following factors: (1) spores germinated at the termination of their after-ripening period; (2) germination at low temperatures, 12° C.; (3) acid solutions; (4) nutrient solutions such as apple juice, honey, Cohn's and Laurent's. In some old cultures, lateral sporidia developed in these nutrient solutions branched, bore cross-walls and duplicated the original promycelium and its parts. This was especially noticeable in honey solutions.

So many unsuccessful attempts were made to discover conditions under which promycelia would form typical sporidia that the author believes typical sporidia seldom, if ever, form on the promycelia of germinating smut spores from timothy. The types of germination for these spores seemed to fall in the same category as those of *U. tritici*, *U. dura* and *U. nuda*, cited by Paravicini (27) as "the mycelium is the whole state of the matter." For this reason, Herzberg (14) assigned organisms with spores germinating in this manner to the genus *Ustilagidium*.

Brefeld (3) and Bauch (2) showed that germinating spores of *U. longissima* formed primary sporidia which under favorable conditions, either fused with other sporidia, budded or developed into mycelial threads. Paravicini (27) also showed that species of *Ustilago* form these buds or secondary sporidia which may fuse forming a conidium and this in turn develop a mycelial thread.

Primary sporidia were sometimes cut off the tips of a short promycelium-like growth protruding from the spore or remained within the spore walls.

These were observed especially among spores from timothy after-ripened during an unusually short period, treated with organic acids previous to germination, germinated in a weak solution of organic acid at low temperatures, as 15° C., or at high temperatures of 29° to 30° C. (Plate XV, Fig. 8-16). A unicellular primary sporidium sometimes developed, dividing "in situ" to form a necklace of cells which gave the appearance of a promycelium composed of several short uninucleated cells (Plate XV, Fig. 16). In weak organic acids and nutrient solutions, some primary sporidia formed buds which appeared uninucleated in stained slides. In three cases primary sporidia fused, the contents of one passed into the other and formed a conidium which developed a mycelial thread. Primary sporidia were observed emerging from the smut spore and budding.

Primary sporidia varied from 3 to 16 microns in length and from 1.5 to 6 microns in width. Most of those observed in stained slides contained two nuclei and granular protoplasm with vacuoles. On stained slides, it was difficult to distinguish primary sporidia from promycelia as the final outcome of germination could not be further observed without developing special technique. (Plate XV, Fig. 8-10.) Some of the apparently shorter primary sporidia were uninucleate. The above observations of germinating smut spores from timothy may be summarized.

1. Typical germination in water produces a long promycelium bearing one to five lateral sporidia, branched or unbranched, with the protoplasm assembled mostly in the tip or tips.

2. The promycelia and lateral sporidia sometimes possess cross-walls, branches or lateral sporidia.

3. Primary sporidia are formed directly from the spore or within spores similar to those formed in *U. longissima*.

4. Typical sporidia are seldom if ever formed.

5. Sporidia sometimes fuse forming conidia which develop mycelia.

6. Buds are formed on primary sporidia but sometimes emerge directly from the germinating smut spore.

7. The typical germination of these smut spores is similar to the germination of the spores of *U. tritici*, *U. nuda* and *U. dura*.

Germination of spores from redtop (Plate XVI, Figs. 1, 2, 4).—Smut spores from redtop were after-ripened, incubated, germinated and stained by methods previously described for the smut spores from timothy.

The granular protoplasm sometimes advanced to the tip of the promycelium; other times, the content was granular and bore one to five branches or lateral sporidia. The promycelia and sporidia bore cross-walls. Primary sporidia sometimes protruded from the spore but at other times remained within it. Uninucleated buds were formed from spores, primary sporidia and other buds.

Thus the germination of the spores from redtop was of the same type and agreed favorably with the partial description by Clinton and Osner. However, no clamp connections between promycelial cells were observed in the numerous spore germination cultures. As far as could be determined, the germination of the spores from redtop was identical with that previously described for spores from timothy.

Germinated spores from June grass (Plate XVI, Figs. 3, 5-7).—Observations of numerous spore germination cultures showed that the typical germination for most of the smut spores from June grass was similar to the germination already described for the smut spores from timothy and redtop. However, in two lots of germinating spores, the promycelium together with its lateral sporidia separated from the spore and a disturbance of the liquid caused some of the sporidia to separate from the promycelium. In different cultures, two of these free sporidia came in contact, fused either laterally or apically and formed a conidium which developed a mycelial thread or buds.

When after-ripened smut spores were treated with acids and incubated in weak solutions of organic acids or in water, primary sporidia sometimes developed acropically and apparently divided in place giving the appearance of a promycelium composed of two to five short cells. These primary sporidia sometimes bore buds laterally and apically. (Plate XVI, Fig. 3.) As far as determined, most of these buds were uninucleate when formed.

Thus the common type of germination for the smut spores from timothy, redtop and June grass was similar with the additional fusion of lateral sporidia observed in the germinating smut spores from redtop.

Germinating smut spores from orchard grass (Plate XVI, Figs. 8-10).—While fewer cultures of germinating smut spores from orchard grass than from timothy were under observation, yet there were sufficiently large numbers to show no decided, external differences in the type of germination. However, some lateral sporidia formed exceptionally long, septate hyphae. Otherwise, the common type of germination for the spores from timothy, redtop, June and orchard grass was the same.

RELATION OF TEMPERATURE TO GERMINATION

The influence of temperature on the germination of these smut spores was determined by incubating the spore samples in an Altmann incubator where the temperatures of the compartments ranged from 6° to 20° C., at approximately 2° intervals. For temperatures ranging from 20° to 38° C. incubators and electric ovens were employed. The temperatures were read three times daily and only averages were reported in the results. Where neither the liquid nor definite temperatures are stated for the ger-

mination tests, a room temperature of about 20° C. and distilled tap water were employed.

Fresh smut spores from all four hosts were set to germinate at temperatures ranging from 0° to 38° C. and the samples interchanged from low to high temperatures. Spores that had remained outdoors during zero weather were tested for germination at the various temperatures. All results were negative and showed temperature is not the important factor for inducing the germination of the fresh smut spores.

As there was no experimental evidence on the relation of temperature to the germination of spores of *Ustilago striaeformis*, after-ripened spores were incubated at the different temperatures stated above to determine the minimum, optimum and maximum temperatures. Data were averaged from three trials and the results are shown in figure 1.

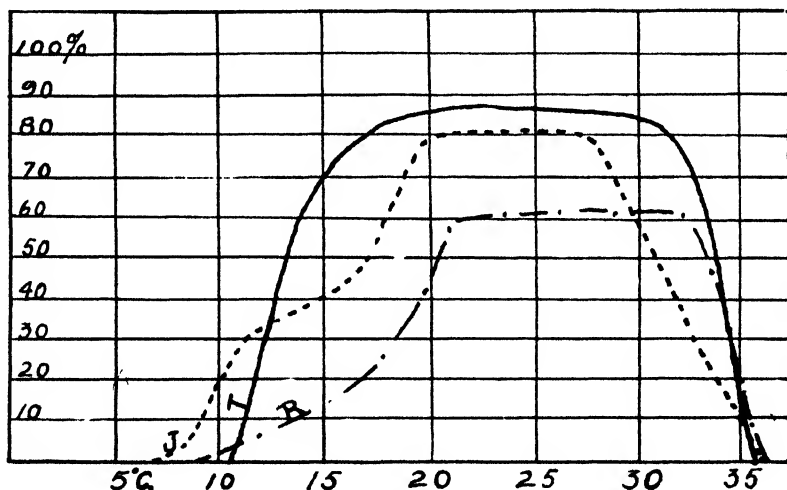


Fig. 1. Curves showing the effect of different temperatures on the percentage of germination of after-ripened smut spores from three different hosts; timothy (T), redtop, (R), and June grass (J).

The following conclusions were drawn from these germination tests:

1. The after-ripened smut spores from timothy show a minimum germination at 12° C.; optimum, at 25° C., with a range from 20° to 30° C., the maximum being 37° C.

2. In general, the cardinal temperatures for the germination of the smut spores from timothy, redtop, and June grass may be stated: minimum, 7° C., optimum, 22° C., maximum, 35° C.

3. After-ripened smut spores from orchard grass were set to germinate at 8°, 22°, and 38° C. The results showed that the cardinal temperatures

for the germination of the smut spores from orchard grass are about the same as those stated above for timothy, redtop, and June grass.

TAXONOMY

Only a brief history of the taxonomy of this pathogen need be given here as it has been reviewed by Osner (19) and others. The following is a list of the more important synonyms for the fungus as it has been described on various hosts:

Ustilago striaeformis (Westd.) Niessl

1. *Uredo longissima* var. *holci* Cesati. Klotz. Raben. Herb. viv. Mycol. (No. 1498). 1850.
2. *Uredo striaeformis* Westd. Acad. Roy. Belg. Bul. **18**: Ser. 2, 406. 1851.
3. *Tilletia de Baryana* Fischer von Weldheim. Raben. Fungi eur. (No. 1097). 1866.
4. *Ustilago striaeformis* (Westd.). Niessl in Hedwigia **15**: 1. 1867.
5. *Tilletia striaeformis* Oud. Oudemans in Bot. Ztg. **36**: 440. 1876.
6. *Tilletia striaeformis* (Westd.) Magnus. DeToni in Sacc. Syll. fung. **7**: No. 2, 484. 1888.
7. *Ustilago striaeformis* (Westd.) Niessl. Clinton in Ill. Agr. Exp. Sta. Bul. 57: 348-349. 1900.

From the above list of synonyms and the historical sketch of the spore germination studies as previously described, it is to be noted that definite information regarding the germination of the smut spores from timothy, redtop, June and orchard grasses had been wanting and until this information could be supplied, the genus of the organism on all four of these hosts still remained in doubt.

A brief review of the data obtained from this detailed study of germinating smut spores from timothy, redtop, June and orchard grasses demonstrates that the fungus on these four hosts is an *Ustilago*:

1. Sporidia form on the sides of the septate promycelia.
2. Sporidia fuse and form conidia which develop mycelial threads.
3. Primary sporidia develop directly from the spore.
4. Yeast-like buds ("Hafenpilze") may form directly from the spores, primary sporidia and from other buds.
5. The above characters are similar to those assigned the genus *Ustilago* by Brefeld, Rawitscher (28), Paravicini, Bauch and other investigators.
6. Similar types of germination have been reported for *U. nuda*, *U. tritici*, *U. longissima*, *U. dura* and *U. violacea*.

Thus this smut parasitizing timothy, redtop, June and orchard grass should be known as *Ustilago striaeformis* (Westd.) Niessl unless inoculations show there are different species or physiological races on the different grass hosts.

SUMMARY

Results of these spore germination studies may be summarized as follows:

1. The smut spores of *U. striaeformis* are resting spores and, under natural conditions, must pass through a period of after-ripening before germinating. The spores from all four hosts after-ripened best when stored in a damp atmosphere at about 20° C. After-ripening under laboratory conditions required an average period of 240 days; under field conditions about 265 days.

2. Alternate freezing and thawing were not necessary for germination. Smut spores which formed on all four hosts grown in the greenhouse and after-ripened at 20° C. germinated over 80 per cent.

3. After-ripening was hastened three to four weeks by exposing fresh smut spores to the fumes of chloroform for one minute, then submerging them in a 10 per cent citric acid solution for five minutes, washing and storing in a damp atmosphere at 20° C.

4. A sparse germination of spores removed from green tissues of three hosts was obtained by incubating the spores in 0.02 per cent solutions of malic and citric acids. The chemical treatment generally hastened the after-ripening process and, in some instances, seemed to stimulate immediate germination.

5. Good germination of after-ripened smut spores from all four hosts was obtained consistently by incubating the spores in water at 20° C. The after-ripened spores did not germinate on most filter paper, soil and other surfaces unless sufficient moisture was present to float the spores or cover them with a film of solution.

6. The cardinal temperatures for the germination of the smut spores from all four hosts follows: minimum, 7° C.; optimum, 22° C., and a maximum, 35° C. The minimum and maximum temperatures varied several degrees for the spores from different hosts; notably those from timothy where the minimum was at 12° C. and the maximum at 37° C.

7. The type of spore germination for all four hosts was the same. The promycelia were at first unicellular and multinucleate but under certain conditions became multicellular with four to five lateral sporidia; however, occasionally only one lateral sporidium formed on the sides. The granular protoplasm assembled in the tips of unicellular promycelia which sometimes formed lateral sporidia. Secondary spores or buds were usually formed

from conidia, primary sporidia, tips of the promycelia and other buds. Under certain conditions primary sporidia were formed directly from the spore. Lateral sporidia sometimes fused and formed conidia which developed buds and mycelial threads.

8. The germinated spores failed to form saprophytic mycelium and typical sporidia on decoctions, agars and other substrata.

9. The germination of these spores as well as the structure of the germinated spores was similar to those described for other smuts in the genus *Ustilago*; notably, *U. tritici* (Bjerkander) Winter; *U. nuda* (Jensen) Kellerman et Swingle; *U. hordeii* (Persoon) Kellerman et Swingle; *U. avenae* (Persoon) Jensen; *U. violaceae* (Persoon) Fuckel; *U. longissima* (Sowerby) Tulasne and others.

LITERATURE CITED

- (1) ANDERSON, P. J. Development and pathogenesis of the onion smut fungus. Massachusetts Agric. Exp. Sta. Tech. Bul. 4: 99-133. 6 fig. 1921. Literature cited, p. 132-133.
- (2) BAUCH, R. Über *Ustilago longissima* and ihre varietät *Macrospora*. Zeitschr. Bot. 15: 241-279. Pl. 3. 1923. Zitierte literatur, p. 278.
- (3) BREFELD, OSCAR. Die Brandpilze I. (Ustilagineen). Untersuchungen aus dem Gesamtgebiete der Mykologie. Heft 5. 13 p. Leipzig. 1883.
- (4) ———. Die Brandpilze II. Die Brandkrankheiten des Getreides. Untersuchungen aus dem Gesamtgebiete der Mykologie. Heft 11. P. 1-98, pl. 1-5. Münster. 1895.
- (5) ———. Die Brandpilze und die Brandkrankheiten V. Untersuchungen aus dem Gesamtgebiete der Mykologie. Bd. 15. 151 p., 7 pl. Münster. 1912.
- (6) ———, and R. FALCK. Blossom infection by smuts and natural distribution of smut diseases. Pt. 13. Smut Fungi (Hemibasidia IV). Translation by F. Dorrance. 59 p., 2 pl. Münster. 1912.
- (7) CLINTON, G. P. The smuts of Illinois agricultural plants. Illinois Agric. Exp. Sta. Bul. 57: 289-360. Pl. A-C. 1900.
- (8) ———. North American Ustilagineae. Proc. Boston Soc. Nat. Hist. 31: 329-529. 1904. Literature, p. 505-524.
- (9) ———. The Ustilagineae, or smuts of Connecticut. Connecticut State Geol. and Nat. Hist. Survey Bul. 5: 43 p., 7 pl. 1905.
- (10) ———. Ustilaginales. North Amer. Flora 7: 1-82. 1906.
- (11) DAVIS, W. H. Staining germinating spores. Phytopath. 12: 492-494. 1922.
- (12) FISCHER VON WALDHEIM, A. Beiträge zur Biologie und Entwicklungsgechiehte der Ustilagineen. Jahrb. Wiss. Bot. 7: 61-144. Pl. 7-12. 1867. Bibliographical footnotes. Translation in Trans. New York State Agric. Soc. 30: 280-354. Pl. 1-6. 1872.
- (13) GUILLIERMOND, A. (Trans. & Rev. by F. W. Tanner.) The Yeasts. 424 p. New York. 1920. Bibliographical index, p. 381-409.
- (14) HERZBERG, PAUL. Vergleichende Untersuchungen über landwirtschaftlich wichtige Flugbrandarten. Halle. 1895. Beitr. Physiol. u. Morph. Organismen 5: 1-36. 3 pl. 1895.

- (15) JENSEN, C. N. Fungous flora of the soil. New York Cornell Agric. Exp. Sta. Bul. 315: 415-501. *Fig. 100-134*. 1912. Bibliographical footnotes.
- (16) JOHNSON, A. G., and R. J. HASKELL. Diseases of cereals and forage crops in the United States in 1919. United States Dept. Agric. Bur. Plant Indust. Plant Disease Survey Bul. Suppl. 8. 81 p. 1920.
- (17) KNIEP, HANS. Über *Urocystis anemones* (Pers.) Winter. Zeitschr. Bot. 13: 289-311. Pl. 3. 1921. Zitierte literatur, p. 309-310.
- (18) MAGNUS, P. Die Ustilagineen (Brandpilze) der Provinz Brandenburg. Verhandl. Bot. Ver. Brandenburg 37: 66-97. 1896.
- (19) OSNER, G. A. Leaf smut of timothy. New York Cornell Agric. Exp. Sta. Bul. 381: 189-230. Pl. 17, fig. 45-59. 1916. Bibliography, p. 226-230.
- (20) PAMMEL, L. H. Smut on timothy grass. Prairie Farmer 58: 484. 1 fig. 1886.
- (21) ———. Diseases of forage plants. Iowa Improved Stock Breeders' Assoc. Proc. 16: 140. 1889.
- (22) ———. New fungous diseases of Iowa. Jour. Mycol. 7: 95-103. 1892.
- (23) ———. Some fungous diseases of Iowa forage plants. (Abstract.) Iowa Acad. Sci. Proc. 1: 93-94. 1892.
- (24) PAMMEL, L. H. Notes on some fungi common during the season of 1892, at Ames. Iowa Agric. Sci. 7: 20-27. 1893.
- (25) ———. Diseases of plants at Ames, 1894. Proc. Iowa Acad. Sci. 2: 201-208. 1895.
- (26) ———, J. B. WEEMS and F. LAMSON-Scribner. Grasses of Iowa, I. Iowa Agric. Exp. Sta. Bul. 54: 71-344. 137 fig. 1901. Bibliographical footnotes.
- (27) PARAVICINI, EUGEN. Untersuchungen über Verhalten der Fortpflanzung der Brandpilze. Ann. Mycol. 15: 57-96. 1917. Literatur, p. 89-91.
- (28) RAWITSCHER, F. Beiträge zur Kenntnis der Ustilagineen II. Zeitschr. Bot. 14: 273-296. 2 Abb. 1922. Zitierte literatur, p. 295.

DESCRIPTION OF PLATES

PLATE XIV

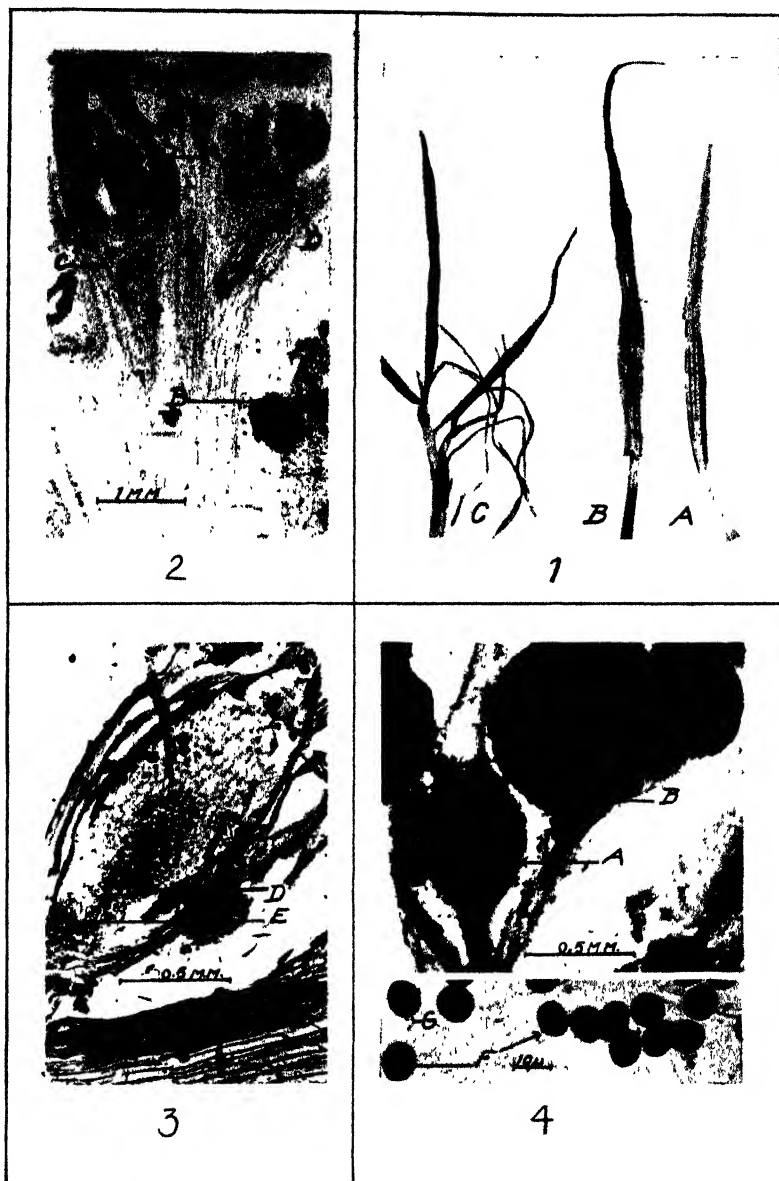
Figures 2, 3, 4, photomicrographs of sections stained with safranin-gentian-violet orange G.

Fig. 1. A. Young infected timothy leaf. B. An old infected timothy leaf showing rifts starting along the striae. C. An infected timothy plant; dwarfed and leaves shredded.

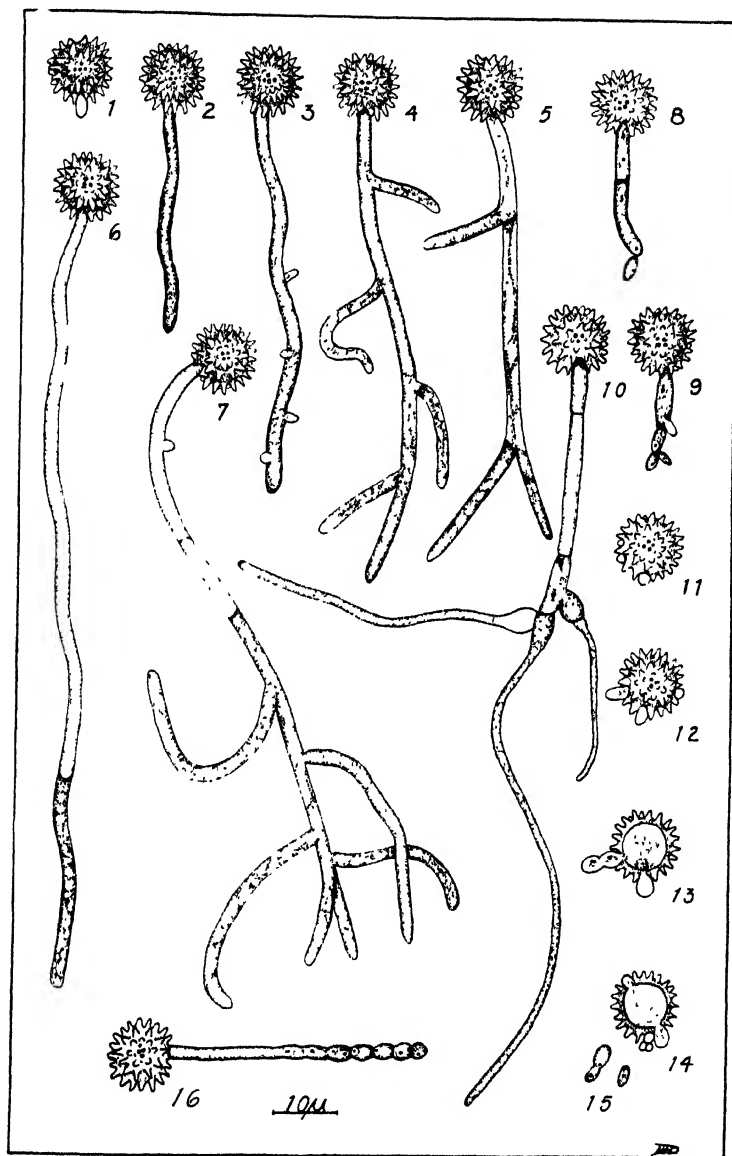
Fig. 2. Section of a redtop panicle infected with *U. strueiformis*. A. Mycelium in the ovary. B, E. Pustules of spores in glume and lemma. C, D. Mycelium in rhachis and rhachilla.

Fig. 3. Section of a timothy spikelet showing an ovary with mycelium. D. A portion of which has advanced through culm rhachis and rhachilla E, to the ovary D.

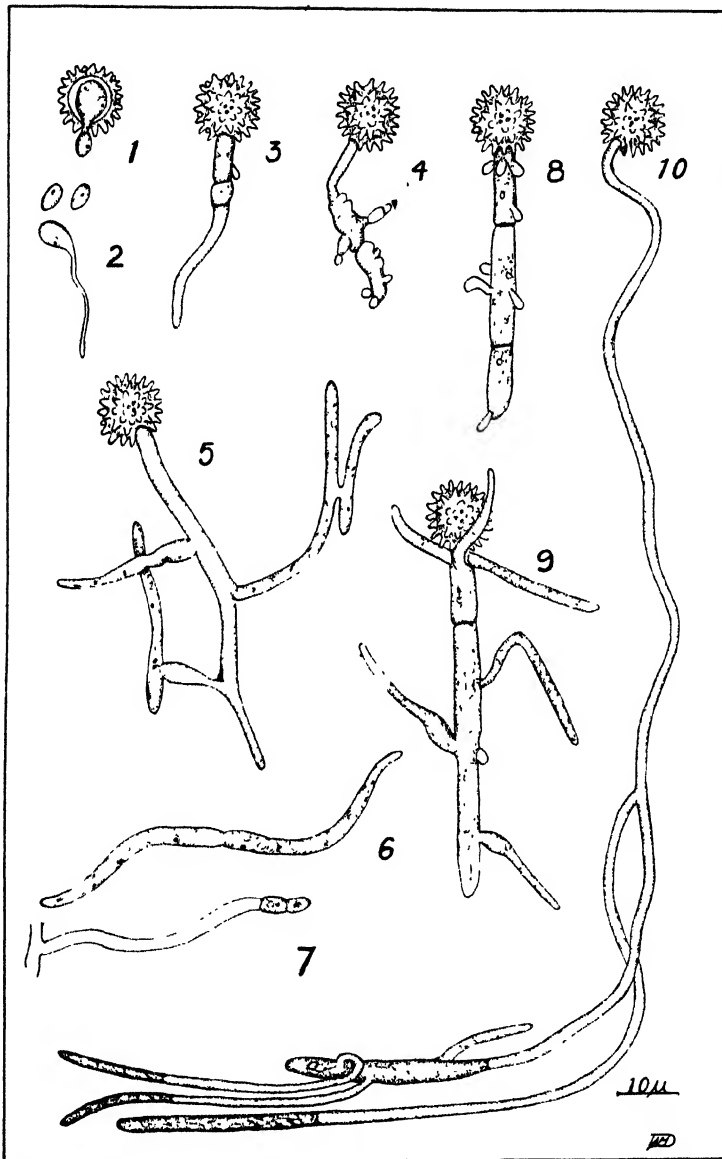
Fig. 4. A-B. Ovaries of redtop filled with spore masses. G, F. Germinated spores from timothy. F. Rifts in the spore through which the promycelium emerged. G. Spore with ecinulations.



AETIOLOGY OF THE LEAF SMUT OF TIMOTHY



GERMINATING AFTER-RIPENED SMUT SPORES FROM TIMOTHY



GERMINATION OF SMUT SPORES FROM REDTOP JUNE GRASS AND ORCHARD GRASS

PLATE XV

Spores incubated in distilled water at 20° C. unless otherwise stated; from camera lucida drawings.

Fig. 1. Promycelium after 12 hours incubation at 25° C. Fig. 2. Granular protoplasm filling the promycelium; 18 hours incubation. Fig. 3. Lateral sporidia forming on the sides of the promycelium; 48 hours incubation. Fig. 4. Lateral sporidia after 72 hours incubation. Fig. 5. Cross-wall in the promycelium and lateral sporidium; incubated 72 hours and stained. Fig. 6. Granular protoplasm assembled in the tip of the promycelium leaving the remainder of the promycelium hyaline; 24 hours incubation. Fig. 7. Five sporidia from a promycelium previously in the condition described in fig. 6. Incubated in honey for 48 hours. Fig. 8. Primary sporidia and bud. Fig. 9. Primary sporidia and buds incubated in apple juice for 20 hours. Fig. 11-14. Buds emerging directly from an after-ripened spore incubated at 29°. Drawings show the changes at about fifteen minute intervals. Fig. 15. Buds from stained germinated spores. Fig. 16. A row of buds on a primary sporidium. Spores incubated in a 0.05 per cent malic acid solution and stained.

PLATE XVI

Stages of after ripened smut spores from redtop (Fig. 1, 2, 4), June grass (Fig. 3, 5-7) and orchard grass (Fig. 8-10). The general type of germination for each of these three hosts is omitted but is similar to that figured for germinated spores from timothy in plate II. Spores germinated in distilled water at 20° C. unless otherwise stated; from camera lucida drawings. Fig. 1. A bud (sporidium) emerging from the spore. From a stained specimen. Fig. 2. Buds; one with a hypha. Fig. 3. Primary sporidia; one forming a hypha, another buds. Fig. 4. Primary sporidia bearing buds. Fig. 5-6. Fusion of lateral sporidia. After-ripened spores incubated for 4 days. Fig. 7. Buds on the end of one of two fused lateral sporidia. Fig. 8. Primary sporidia bearing buds; incubated 48 hours in equal parts of Laurent's solution, molasses and water. Fig. 9. Hyphae developed from buds on primary sporidia. Incubated as described in fig. 8. Fig. 10. Exceptionally long promycelium and germinating lateral sporidia with granular protoplasm in the tips. Spores after-ripened 237 days and incubated 5 days.

REACTIONS OF SELFED LINES OF MAIZE TO *USTILAGO ZEAE*

H. K. HAYES, E. C. STAKMAN, FRED GRIFFEE
AND J. J. CHRISTENSEN¹

INTRODUCTION

Corn smut, caused by *Ustilago zeae*, cannot be prevented by ordinary control measures. The pathogene produces enormous numbers of chlamydospores; they are widely disseminated by the wind, and when they germinate in suitable nutrient solutions, such as manure decoction and soil infusions, countless numbers of sporidia are produced. The sporidia bud in a yeast-like manner, and in turn produce countless numbers of other sporidia. Thus the pathogene can exist as a saprophyte and propagate itself almost indefinitely in manure piles, compost heaps, and possibly in the soil. Both the chlamydospores and the sporidia are resistant to unfavorable conditions. The former retain their viability for as long as eight years, while the sporidia can withstand desiccation and other unfavorable conditions for several months (Piemeisel, 1917). Consequently there almost always is an abundant supply of inoculum in corn-growing regions. For this reason, crop rotation and cultural practices are ineffective, and seed treatment is valueless, because young growing tissues of corn plants of any age may be infected. Immunization therefore is the most promising method of control.

That corn smut sometimes does considerable damage is well known. But it probably is not generally realized that, even under favorable growing conditions, a fairly large percentage of ears may be completely destroyed. This was true in 1921 in a field of first generation corn crosses and their parents at University Farm, St. Paul. In this year a considerable number of ears were discarded because they were so badly infected with smut. The field on which this test was made is in a two-year rotation of corn and small grain. The percentage of ears which were discarded because of injury by smut ranged from 1.4 per cent to 8.8 per cent in six first generation corn crosses and averaged 1.9 per cent in two dent varieties, while the injury to the ears of three flint varieties ranged from 3.9 per cent to 13.4 per cent.

Jones (1918) described differences in susceptibility of strains of maize to smut attacks. The differences were hereditary and the F_1 generation of a cross between a susceptible and resistant strain was resistant while segregation occurred in the F_2 generation. Probably all plant breeders who have grown self-fertilized strains of maize have observed the fact that some strains are more susceptible than others to attacks of corn smut. Disease

¹ Published with the approval of the Director as paper No. 458, Journal Series of the Minnesota Agricultural Experiment Station, St. Paul, Minn.

resistance in maize is one of the characters which can be best studied by the use of self-fertilized lines. Accordingly, in 1918, it was decided to determine the possibility of developing varieties of corn resistant to smut. The method of attack was selection in self-fertilized lines² under infection conditions.

EXPERIMENTAL METHODS AND MATERIAL

The Selfed Strains.—Although selfed strains were available, it was decided to start the experiment with commercial varieties and build up self-fertilized strains under infection conditions. Accordingly the following seven varieties of corn were selected: Rustler, Minnesota No. 13, Northwestern, Minnesota No. 23, King Phillip, Longfellow, and Squaw. With the exception of Squaw and Minnesota No. 23, which are early maturing, the varieties were adapted for the conditions in Central Minnesota. The first year each variety was grown in a row consisting of 82 plants, the plants being spaced a distance of one foot apart in the row. Two seeds were planted in each hill and the hills were thinned to a single plant basis. Vigorous plants were chosen for selfing and both infected and non-infected plants were selfed in order to determine the ease of isolating resistant and susceptible strains.

In addition to the seven varieties a few selfed strains were included. Two strains were obtained from D. F. Jones, of the Connecticut station, under the numbers 1-6-1-3-4-4-4-2-5-3-1-5 and 1-9-1-2-4-6-7-5-6-2-4 and a self-fertilized flint strain was also grown. Each of these three strains had been selfed approximately 10 generations. The two strains from Connecticut were two of those which appeared highly resistant to smut as reported by Jones.

In 1920 each selfed strain was grown in three short rows which were systematically distributed over the experimental area, and in 1921 to 1923 inclusive each strain was grown in two systematically distributed rows. From 50 to 75 plants of each strain were grown each year. At maturity the ears from 20 plants, excluding those which had been self-fertilized, were harvested. After the ears were thoroughly cured, data were taken on number of good ears, number of nubbin ears, average length of ear, average size of endosperm of seed, etc. The yield data were taken in order that a study might be made of the relation of smut infection and yielding ability of selfed strains.

Producing the Epidemic.—A considerable amount of smut was collected and stored over winter for the purpose of inducing the epidemic. The epidemic was induced by two methods. Smut spores were mixed with manure

² For a discussion of selection in self-fertilized lines see East and Jones (1921), Hayes and Garber (1919), Hayes (1922) and Jones (1920).

about the time the corn was planted, as sporidia develop rapidly in manure and after the corn was up the manure was spread over the field. Beginning when the plants were about three feet high they were sprayed about every ten days in the evening with a water suspension of smut sporidia.

Notes were taken throughout the season for each individual plant on the sort and place of infection, if any. After several years' experience it was concluded that data on infection should be taken at three periods: the first notes at about tasseling time, the next about a month later, and then a note on ear infection at maturity.

The place of plant infection was noted as: S, sucker; E, ear; Eb, ear base; Et, ear tip; L, leaf; Lb, leaf base; M, main stalk; and T, tassel. Multiple infection was noted by Mi and incipient infection by In. The size of the smut boils was estimated by placing them in three groups: S, less than two inches in one or both dimensions; M, of medium size, larger than S and smaller than L; and L, at least 4 inches in diameter in more than one direction. In summing up the notes on total infection the percentage of plants infected, barring incipient infection, was taken as the total percentage infection. Incipient infection was considered to be an indication of resistance because the smut boil starts to develop but does not grow very large and dries up before it ripens. Because of its importance the percentage of ear infection was computed separately.

EXPERIMENTAL RESULTS

Corn is in a highly heterozygous condition under normal conditions. The ease of isolating homozygous strains for resistance or susceptibility to smut depends, in a large measure, on the number of genetic factors involved. If resistance or susceptibility were differentiated by a single factor pair, half of the plants in a field of corn would be homozygous for either resistance or susceptibility and the other half would be in a heterozygous condition. With two factors only one fourth of the plants under normal conditions would be homozygous for various degrees of resistance or susceptibility. The different possible types which could be isolated in a homozygous condition by self-fertilization depends naturally upon the genetic factors involved. The only means of knowing how many factors are involved is to study crosses between types which differ in resistance or susceptibility. The present paper is chiefly a report of the isolation of selfed lines which differ in their heritable mode of reaction to attacks of the smut organism.

Commercial varieties were grown under induced epidemic conditions and individual plants were self-pollinated. Approximately 60 different self-fertilized lines were grown the following year. Some lines were only

slightly infected with smut while others appeared very susceptible. Within several of these self-fertilized lines both infected and non-infected plants were again self-pollinated. The purpose was to determine the comparative susceptibility or resistance of the progeny of infected and non-infected plants of the same selfed line. The results are presented in table 1.

TABLE 1—*A comparison of the progeny of self-fertilized infected and non-infected plants of first generation selfed lines of maize. 1920.*

Variety	1920 selfed strain No.	Infection of parent stalk	Total percentage of infection, 1921	Difference
Minnesota 13	2100	Infected	53.0	— 31.5
		Non-infected	84.5	
Rustler	2400	Infected	26.0	+ 6.0
		Non-infected	20.0	
N. W. Dent	2500	Infected	54.5	+ 32.5
		Non-infected	22.0	
		Non-infected	63.0	
N. W. Dent	2700	Infected	47.0	+ 10.5
		Non-infected	36.5	
N. W. Dent	2800	Infected	39.0	+ 21.0
		Non-infected	18.0	
N. W. Dent	3000	Infected	37.5	+ 4.5
		Non-infected	33.0	
Longfellow	3500	Infected	4.5	— 13.5
		Non-infected	18.0	
		Non-infected	29.0	
Longfellow	3600	Infected	73.0	— 11.5
		Non-infected	84.5	
King Phillip	4000	Infected	58.5	+ .5
		Non-infected	58.0	
King Phillip	4200	Infected	56.5	+ 28.5
		Non-infected	28.0	
King Phillip	4300	Infected	17.0	— 7.0
		Non-infected	24.0	
Squaw	4400	Infected	29.5	— 8.5
		Non-infected	38.0	
		Non-infected	25.0	
		Non-infected	12.5	

Sixteen comparisons are available of the infection of the progeny of infected and non-infected parent plants of strains of corn which have been selfed for one year. These sixteen comparisons are made within twelve different strains, i.e., in three cases the progeny of an infected parent of a first year self-fertilized strain is compared with two progenies of non-

TABLE 2—*The percentage of plant and ear infection of self-fertilized strains of corn and of the normal varieties from which these strains were isolated.*

Variety	No. years selfed 1923	1923 Cult No.	Total percentage infection					Percentage ear infection				
			1920	1921	1922	1923	Ave.	1920	1921	1922	1923	Ave.
Minnesota No. 13	0	2100		19.0	51.0	12.0		2.1	0.0	0.0		
" "	4	700	19.1	58.0	62.8	85.5	56.4	6.4	32.0	26.6	16.8	20.5
" "	4	800	2.3	10.5	65.6	14.0	23.1	0.0	0.0	0.0	2.0	0.5
" "	4	900	9.3	14.0	40.0	21.8	21.3	0.0	0.0	4.0	4.5	2.1
" "	3	2200		23.8	29.3	6.7				0.0	2.3	
" "	3	2300		23.8	11.2	6.1				0.0	2.0	
" "	3	2400		23.8	31.1	24.1				0.0	4.0	
" "	4	2500	2.3	2.0	26.7	22.3	13.3	0.0	0.0	4.2	6.8	2.8
" "	4	2600	2.3	10.5	40.3	27.8	20.2	0.0	0.0	4.3	5.9	2.6
Rustler	0	2700			22.0	23.2				0.0	0.0	
" "	4	1000	33.3	84.5	100.0	98.0	79.0	5.6	11.2	21.3	28.0	16.5
" "	4	1100	3.7	28.5	2.5	12.1	11.7	0.0	14.4	0.0	4.0	4.6
" "	4	1200	6.5	2.0	2.2	12.6	5.8	2.2	0.0	0.0	0.0	0.6
" "	4	2800	33.3	53.0	88.2	94.7	67.3	5.6	14.1	38.1	20.9	19.7
" "	4	2900	3.7	28.5	12.5	35.1	20.0	0.0	14.4	2.1	22.9	9.9
" "	4	3000	3.7	16.0	12.5	23.1	13.8	0.0	0.0	0.0	10.5	2.6
" "	4	3100	6.5	24.5	29.1	43.1	25.8	2.2	0.0	4.2	0.0	1.6
" "	4	3200	11.1	20.0	27.1	12.4	17.7	1.8	0.0	0.0	0.0	0.5
" "	4	3300	11.1	20.0	49.6	18.4	24.8	1.8	0.0	4.2	4.0	2.5
N. W. Dent	0	3400			61.4	53.0				0.0	4.1	
" "	4	3500	22.6	63.0	95.7	75.2	64.1	5.7	6.2	2.2	15.3	7.4
" "	4	3600	22.4	36.5	33.4	32.2	31.1	10.3	14.2	10.5	2.3	9.3
" "	4	3700	22.4	47.0	89.9	92.6	63.0	10.3	4.1	12.4	24.0	12.7
" "	4	3800	8.5	18.0	38.0	15.8	20.1	2.1	4.0	0.0	0.0	1.5
" "	4	3900	8.5	18.0	59.4	49.3	33.8	2.1	4.0	0.0	26.2	8.1
" "	4	4000	5.0	42.0	42.0	16.6	26.4	1.7	2.0	0.0	0.0	0.9
" "	4	4100	5.0	24.0	32.4	22.4	21.0	1.7	6.0	2.0	13.9	5.9
" "	4	4200	20.0	33.0	75.0	94.8	55.7	6.7	4.0	7.5	36.1	13.6
Minnesota No. 23	4	4300	20.0	56.5	81.7	77.1	58.8	4.0	36.8	46.7	59.7	36.8
" "	4	4400	50.0	80.5	63.4	77.6	67.9	17.9	18.4	4.0	8.2	12.1
" "	4	4500	65.6	88.0	93.8	56.2	75.9	27.9	12.5	2.1	4.7	11.8
" "	4	4600	38.7	30.0	59.3	29.8	39.5	9.7	2.1	10.3	2.7	6.2
Longfellow	0	4700			38.9	32.4				6.1	20.6	
" "	1	4800				74.4					48.9	
" "	4	4900	15.5	18.0	44.9	6.0	21.1	11.1	0.0	0.0	0.0	2.8
" "	4	5000	32.6	73.0	83.7	65.9	63.8	16.3	35.4	20.9	26.5	24.8
" "	4	5100	14.7	14.0	2.3	12.4	10.9	5.9	14.2	0.0	6.2	6.6
King Phullip	0	5200			43.2	41.7				4.5	15.0	
" "	4	5300	31.0	58.0	66.8	97.5	63.3	22.4	41.7	51.3	95.0	52.6
" "	4	5400	31.0	58.0	34.7	80.0	50.9	22.4	41.7	25.6	70.0	39.9
" "	4	5500	31.0	58.5	70.1	57.1	54.2	22.4	39.6	37.1	48.0	36.8
" "	4	5600	37.5	44.5	61.3	41.8	53.8	12.5	12.9	4.6	15.7	11.4
" "	4	5700	24.1	24.0	36.5	64.7	37.3	0.0	14.0	12.2	46.9	18.3
" "	4	5800	24.1	17.1	38.8	27.0	26.8	0.0	4.2	2.1	8.0	3.6
Squaw	0	5900			54.5	39.4				15.2	14.6	
" "	4	6000	21.5	12.5	80.0	80.3	48.6	7.7	8.2	8.9	12.8	9.4
" "	4	6100	21.5	25.0	34.3	42.6	30.9	7.7	4.3	8.5	5.0	6.4
" "	4	6200	21.5	29.5	38.5	69.7	39.8	7.7	0.0	8.7	28.1	11.1
1-9-1, etc.	14	1700	12.9	51.5	60.9	67.3	48.2	1.6	0.0	0.0	0.0	0.4
1-6-1, etc.	14	1800	18.4		48.0	71.7		8.6		5.0	37.0	
69-6, etc.	14	1600	29.9	21.0	34.5	24.2	27.4	9.5	21.0	15.6	0.0	10.4

infected plants of the same strain. If the progeny of the infected parent plant is more severely infected than the progeny of the non-infected parent plant the difference is presented in the table as a plus difference. When the progeny of the non-infected plant is the more severely infected, the difference is presented as a minus difference. There were 7 minus differences and 9 plus differences. The sum of the plus differences was 125 and of the minus differences 105. These results prove that under the conditions of the experiment it makes little difference whether a selfed plant is infected or not. The important fact is the hereditary characters of the strain. In table 2 data are presented on the total percentage of smut infection of the self-fertilized strains. The two strains obtained from Jones, of Connecticut, were rather susceptible under the conditions of the experiment, although not as susceptible as some selfed strains produced under induced epidemic conditions. The long time self-fertilized flint strain, 69-6, etc., apparently bred true for an intermediate degree of infection, which indicates that moderately susceptible strains can be secured.

Probable errors for total percentage of smut infection were computed in 1920 and 1921 by the pairing method. In brief, this method consists of obtaining the deviation in percentage of smut infection of each two pairs of plots of the various selfed lines. By dividing the average deviation in per cent for all pairs by the \sqrt{n} where n represents the number of systematically distributed plots, a probable error for the method of test has been computed. This method was suggested by Wood and Stratton (1910) and it gives on the average slightly lower probable errors than the use of other methods.

For 1922 and 1923 the probable errors were calculated by the following formula:

$$P.E. = \pm .6745 \frac{\sqrt{\frac{(\text{dev. in } \%)^2}{n}}}{\sqrt{N}}$$

In this formula Σ = summation, dev. in % = deviation in percentage infection of each plot of a selfed strain from the mean of all the plots of that strain, N = number of plots of each strain and n = number of deviations in percentage. The use of this formula gives probable errors of nearly the same magnitude as those obtained from check plots (Hayes, 1923).

Probable errors computed by these methods furnish an average probable error in per cent for the particular experiment. They do not take into account the possible condition that the reaction of some strains is more variable to a particular environmental condition than that of others. Probable errors are presented in table 3.

TABLE 3—*Probable errors in percentage for smut infection.*

Year	Probable error in per cent for percentage smut infection of each selfed line
1920	6.1
1921	7.4
1922	13.3
1923	15.2

The average probable error for the 4 years was computed by the formula $\frac{1}{N} \sqrt{a^2 + b^2 + c^2 + n^2}$ where N represents the number of things averaged and a, b, ... n represent the separate probable errors.

By the use of this formula the average probable error in percentage was found to be 5.6 per cent. This probable error was used to obtain average probable errors of smut infection percentages in selfed lines. Certain of the selfed lines have appeared to be homozygous for their smut reaction and have given consistently high or low percentage infection for each of the four years while other lines show evidence of being heterozygous. The average ear infection and the average total infection of lines which appear to be homozygous is given in table 4.

TABLE 4—*Summary of selfed strains which appear to be homozygous for smut reaction for the period 1920-1923 inclusive.*

Variety	1923 Strain No.	Total percentage infection	Percentage of ear infection
Minnesota 13	700	56.4 \pm 3.1	20.5
"	2500	13.3 \pm 0.7	2.8
Rustler	1000	79.0 \pm 4.4	16.5
"	2800	67.3 \pm 3.8	19.7
"	1200	5.8 \pm 0.3	0.6
"	3000	13.8 \pm 0.8	2.6
"	3200	17.7 \pm 1.0	0.5
N. W. Dent	3500	64.1 \pm 3.6	7.4
"	3700	63.0 \pm 3.5	12.7
"	4200	55.7 \pm 3.1	13.6
"	4000	26.4 \pm 1.5	0.9
Minnesota 23	4400	67.9 \pm 3.8	12.1
"	4500	75.9 \pm 4.3	11.1
Longfellow	5000	63.8 \pm 3.6	24.8
"	5100	10.9 \pm 0.6	6.6
King Phillip	5300	63.3 \pm 3.5	52.6
"	5500	54.2 \pm 3.0	36.8

Comparing the two strains 700 and 2500 of Minnesota 13, a difference for total infection of 43.1 \pm 3.2 is obtained. The chances are very great that this difference is significant. Certain strains appear to be homozygous for an intermediate type of susceptibility. Thus Northwestern Dent strain

4000 had an average infection of 26.4 ± 1.5 while Rustler Dent strain 1200 had an average infection of 5.8 ± 0.3 . Strains 4000 and 1200 differ in smut reaction by the percentage infection of 20.6 ± 1.5 . The chances are also very great that this is a significant difference.

The place of infection on the plant is a strain characteristic. Thus strain 1-9-1, etc., which was resistant under Connecticut conditions, produced an average total infection of 48.2 per cent and an average ear infection of only 1.5 per cent, while strain 69-6, etc., had only an average total infection of 24.2 per cent, but an average ear infection of 10.4 per cent. One strain which was under observation in the Plant Breeding Nursery for several years produced large smut boils near the base of the plant on a large percentage of the plants. This tendency was noted from year to year. Some strains are severely infected in the tassel and scarcely ever infected in other parts of the plant, while still other strains, such as King Phillip, Strain 5300, produced a very high percentage of ear infection. The extent to which total infection is inherited from year to year is demonstrated by the calculation of correlation coefficients for smut infection in different seasons. The correlation coefficients would presumably be larger in homozygous than heterozygous material. Coefficients are presented in table 5 and table 6 for the extent to which total percentage infection one year is correlated with total percentage infection in other years and likewise the extent to which ear infection one year is correlated with ear infection in other years.

TABLE 5—*Correlation in selfed strains of maize between total percentage infection of the strains in one year with the percentage infection in other selfed generations.*

Generations correlated	No. of selfed lines	Correlation coefficient
1st and 2nd	58	.696 \pm .046
2nd and 3rd	40	.642 \pm .063
3rd and 4th	38	.712 \pm .054
2nd and 4th	38	.695 \pm .057

These coefficients are uniformly large and prove that the degree of smut infection in selfed lines of maize is dependent upon strain characters.

As has been noted, smut infection on the ear is probably more detrimental to the yielding ability of the corn plant than infection of other parts of the plant. Accordingly correlation coefficients were computed for the purpose of learning to what extent the percentage of ear infection was a strain characteristic. The results of this study are presented in table 6.

These correlations coefficients are somewhat larger than those obtained when total percentage infection was studied. They prove that the selfed lines which differ in reaction to smut can be isolated in a very short time.

TABLE 6—*Correlation in selfed strains of maize between percentage of ear infection in one season with the percentage infection in other selfed generations.*

Generations correlated	No. of selfed lines	Correlation coefficient
2nd and 3rd	40	.859 \pm .028
3rd and 4th	38	.761 \pm .046
2nd and 4th	38	.765 \pm .045

RELATION BETWEEN YIELD AND PERCENTAGE OF SMUT INFECTION

The ears of twenty stalks from each selfed line were harvested for the purpose of learning the comparative vigor of strains. It is realized that a yield test made on this basis is not particularly accurate; but it was hoped that such a test would give some indication of comparative yielding ability. The yields of each group of selfed strains of a variety were averaged separately and a yield index was computed by dividing the average yield of a strain by the average yield of other strains of the same variety which had been self-fertilized for the same length of time. The extent to which yield for one year is correlated with that for another year as computed by this method of obtaining yields may be determined by the use of the correlation coefficient (see table 7).

TABLE 7—*Correlation between yields of third and fourth year selfed lines in 1922 and 1923.*

Yield index. 1922. 3rd year selfed.	Yield index—1923. Fourth year selfed													Total
	18	37	56	75	94	113	132	151	170	189	208	227	246	
56	1		1	1										3
75			1	1	1	1								4
94	1		3	1	1	2	2		1					11
113	1		2	3		4		1					1	12
132	1			1		2				1				5
151											1			1
	4	—	7	7	2	9	2	1	1	1	1	—	1	36

$$r = +.351 \pm .099.$$

Since the method of obtaining yield data is necessarily inaccurate, a high degree of correlation between smut and yield cannot be expected. However, some idea as to whether smut infection influences yielding ability may perhaps be obtained by correlating yield with the percentage of ear infection.

Correlation coefficients are presented in tables 8 to 10 inclusive, which represent the correlation between yield in the 2nd, 3rd, and 4th selfed generation and reaction to smut in these same generations. Each of the three

correlation coefficients is negative, although one is lower than its probable error. The two other coefficients are respectively 2.7 and 2.4 times their probable errors and the chances that they are significant are 13.6:1 and 8.5:1 respectively.

TABLE 8—Correlation between the percentage of smut infection of the ear and yields of lines selfed for two years. (1921).

Per cent smut ear infection. 1921.	Yield index—1921.										Total
	68	75	82	89	103	110	117	131	138	159	
	1	2	3			4		2	2	1	
2											15
7			1	1							2
12	1	1	2		1	1	1			1	8
17									1		1
32							1				1
37			1					1			2
42				1		1					2
	2	3	7	2	1	6	2	3	3	2	31

$$r = -.0003 \pm .0116.$$

TABLE 9—Correlation between the percentage of smut infection of the ear and yields of lines selfed for three years. (1922).

Per cent smut ear infection. 1922.	Yield index—1922.														Total
	54	61	68	75	82	89	96	103	110	117	124	131	138	145	
2				3	1	4	2	3	3	3		2		1	22
7		1							1			1			3
12					2			1	1	1					5
22		1											1		2
27		1	1												2
37								1			1				2
47	1														1
52						1									1
	1	3	1	3	3	5	2	5	5	4	1	3	1	1	38

$$r = -.0274 \pm .0101.$$

REACTION OF F_1 CROSSES BETWEEN SELFED LINES

In 1923 certain F_1 crosses and their parents were compared for smut reaction. The results are presented in table 11.

TABLE 10—Correlation between the percentage of smut infection of the ear and yields of lines selfed for four years. (1923).

Per cent smut ear infection. 1923.		Yield index—1923.														Total
		18	37	56	75	94	113	132	151	170	189	208	227	246	265	
	5	1		3	2	2	3	2	1		1	1		1	1	18
	14	1		2	2		1									6
	23	1			1		4									6
	32			1	2											3
	50						1			1						2
	59	1														1
	68				1											1
	95			1												1
		4	—	7	8	2	9	2	1	1	1	1	—	1	1	38

$$r = -0.248 \pm 0.103$$

TABLE 11—Reaction of F_1 crosses and their parents to attacks of *Ustilago zeae*.

Variety	Parent line or F_1 cross	Generation selfed or F_1	Total per cent smut	Per cent ear smut
Minnesota 13	800	4	14.0	2.0
	900	4	21.8	4.5
	800 \times 900	F_1	8.6	0.0
Minnesota 13	700	4	85.5	16.8
	800 \times 700	F_1	45.1	12.2
Rustler	1000	4	98.0	28.0
	1200	4	12.6	0.0
	1000 \times 1200	F_1	25.0	4.4
Rustler	1100	4	12.1	4.0
	1100 \times 1200	F_1	3.0	0.0
Longfellow	1300	4	7.4	0.0
	1400	4	67.1	30.6
	1300 \times 1400	F_1	60.7	17.8
Longfellow	1500	4	69.1	13.0
	1300 \times 1500	F_1	24.7	10.9

In the study made by Jones the F_1 hybrid approached the condition of the immune parent but dominance of immunity was not perfect. In the F_1 crosses reported here two opportunities are given to compare F_1 crosses between resistant selfed lines with their parents. In both cases the cross is slightly more resistant than either parent. These crosses are (800 \times 900) and (1100 \times 1200) which are crosses between selfed strains of Minnesota No. 13 and Rustler respectively. Four F_1 crosses between resistant and susceptible strains have been compared with their parents. One cross,

800 \times 700, is almost exactly intermediate in percentage of infection. In this case the total percentage of infection of the cross is 45.1 and of the average of the parents 49.8. Two crosses (1000 \times 1200) and (1300 \times 1500) show a partial dominance of resistance while the cross of 1300 \times 1400 is nearly as susceptible as the susceptible parent. In general, then, F_1 crosses between susceptible and resistant selfed strains of corn are intermediate in type of reaction to smut.

SUMMARY

1. The most promising means of controlling corn smut, caused by *Ustilago zeae*, appears to be the development of resistant varieties.

2. Ear infection is more serious than infection of other parts of the plant. Flint varieties appear to be somewhat more susceptible, particularly to ear infection, than dent varieties.

3. A normal variety of corn is in a highly heterozygous condition. Selection in self-fertilized lines appears to be the most promising means of isolating smut-resistant strains of corn.

4. Apparently it is easy to isolate self-fertilized lines which differ in their inherited reaction to smut, which indicates that only a few genetic factors are involved in resistance or susceptibility.

5. The infection in one generation was correlated with the infection in succeeding generations. The correlation coefficients were uniformly large which leads to the conclusion that resistance or susceptibility is a strain characteristic.

6. The localization of the smut on the plant appears also to be a strain characteristic. Some selfed strains were uniformly infected on one of the lower nodes of the stalk, other strains produced a high percentage of ear infection and still others were infected chiefly in the tassel. Some of the very susceptible strains were infected rather generally in all parts of the plant.

7. F_1 crosses between resistant self-fertilized strains were more resistant than either parent while F_1 crosses between resistant and susceptible strains produced an intermediate type of infection.

8. Resistance and susceptibility appear to be conditioned by genetic factors. This leads to the conclusion that the susceptible strains of a variety may be isolated and discarded by means of selection in self-fertilized lines and that resistant strains can be isolated and then used to build resistant varieties.

LITERATURE CITED

- (1) EAST, E. M., and D. F. JONES. Genetic studies on the protein content of maize. *Genetics* 5: 543-610. 8 fig. 1920. Literature cited, p. 609-610.
- (2) HAYES, H. K. Production of high-protein maize by Mendelian methods. *Genetics* 7: 237-257. 5 fig. 1922. Literature cited, p. 257.
- (3) ———. Controlling experimental error in nursery trials. *Jour. Amer. Soc. Agron.* 15: 177-192. 1923. Literature cited, p. 191-192.
- (4) ———, and R. J. GARBER. Synthetic production of high-protein corn in relation to breeding. *Jour. Amer. Soc. Agron.* 11: 309-318. Pl. 10. 1919. Literature cited, p. 317-318.
- (5) JONES, D. F. Segregation of susceptibility to parasitism in maize. *Amer. Jour. Bot.* 5: 295-300. 1918. Literature cited, p. 299-300.
- (6) ———. Selection in self-fertilized lines as the basis for corn improvement. *Jour. Amer. Soc. Agron.* 12: 77-100. 1920. Literature cited, p. 98-100.
- (7) PIEMEISEL, F. J. Factors affecting the parasitism of *Ustilago zeae*. *Phytopath.* 7: 294-307. 1917. Literature cited, p. 307.
- (8) WOOD, T. B., and F. J. M. STRATTON. The interpretation of experimental results. *Jour. Agric. Sci.* 3: 417-440. 10 fig. 1910.

NOTES ON THE LIFE HISTORY OF THE SNAPDRAGON RUST, *PUCCINIA ANTIRRHINI* DIET. & HOLW.

E. B. MAINS¹

The complete life history of the snapdragon rust has never been reproduced. Under greenhouse conditions, at least, the uredinial stage alone is sufficient to maintain the rust, if snapdragons are being propagated by cuttings. If snapdragons are grown from seed, the propagation of the rust by urediniospores can be prevented, care being taken to destroy all rusted snapdragons some time previous to the sowing of the seed. That the urediniospores are not capable of carrying the rust over long periods has been shown by Doran,² who found very little germination after four weeks and none at the end of eight weeks. Out of doors the rust will survive the winter in the uredinial stage whenever rusted plants live over. However, during severe winters, unprotected plants are usually killed in this region.

Another spore stage of the snapdragon rust is known, the teliospore. This is not produced so abundantly as is the urediniospore. Doran states that occasionally the teliospores may be found outdoors in November, while in the greenhouse they are formed only when the plants are gradually deprived of water. Both Doran (*l. c.*, 2) and Peltier³ were unsuccessful in their attempts to germinate the teliospores of this rust. Peltier states that all efforts to germinate the teliospores failed, although they were subjected to alternate wetting and drying, to high and low temperatures, to various outdoor conditions through the winter and summer, and were tested by the gelatine plate method under different conditions. Doran used fresh material, dried material, teliospores produced under glass and produced outside and teliospores overwintered outside. They were tested to 7°, 10°, 12° and 20° C., but in no case was germination obtained. Doran suggests that these spores may be able to germinate only within a very narrow range of temperatures. Hockey⁴ has recently reported the successful germination of the teliospores of *Puccinia antirrhini*. The teliospores used were obtained from greenhouse plants. Hanging drops of teliospores gave 14 per cent germination from material which had been frozen for 1 day

¹ Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

² Doran, W. L. Rust of Antirrhinum. Massachusetts Agric. Exp. Sta. Bull. 202. p. 39-66. 3 pl. 1921. Literature cited, p. 65-66.

³ Peltier, G. L. Snapdragon Rust. Univ. Illinois Agric. Exp. Sta. Bull. 221. p. 535-548. 5 fig. 1919.

⁴ Hockey, J. F. Germination of Teliospores of *Puccinia Antirrhini*. 13th Ann. Rept. Quebec Soc. Protect. Plants, Ann. Rept. 1920-1921: 54-57. Bibliography, p. 57.

outside on a compost heap in January, 1921. As high as 22 per cent germination was obtained after the teliospores had been exposed outside for 14 days. Spores from a plant frozen seven days and kept at room temperature four days and then frozen again for four weeks gave only 2 per cent germination. Seedling plants of snapdragon inoculated with germinating teliospores bearing basidiospores gave no infection, while similar plants inoculated with urediniospores gave characteristic uredinia.

In light of the above, it seems desirable to record the results obtained in this laboratory during the past five years. As part of the investigations being carried on here with the rust of snapdragons, the writer has been considerably interested in obtaining germination of the teliospores in order to determine their function in the propagation and biology of the rust. Several important questions depended for their answer on cultures made with teliospores. Is the rust autoecious or heteroecious? Whether the teliospores may directly infect snapdragon, serving as resting spores to carry the rust over adverse conditions such as winter out of doors, summer in the greenhouse, or whenever the continuous propagation of the rust by urediniospores is interrupted, or whether an alternate host is necessary before the teliospores are of importance, are some of the points to be settled. If the rust is autoecious, then the teliospores are a constant source of danger and the effect of conditions during and following formations on the viability of the teliospores, the length of the dormancy period, conditions determining and favoring germination, are all questions of considerable importance. If, on the other hand, the rust is heteroecious, these questions are of importance only when the alternate host is present and consequently the identity and occurrence of such a host would become the most important question. If the rust is autoecious, it may either be a brachy-Puccinia or an eu-Puccinia. If a brachy-Puccinia, infection from teliospores would give pycnia accompanied by uredinia; if an eu-Puccinia, pycnia accompanied by aecia. If heteroecious, no infection of course would be obtained on snapdragon and the rust must be an eu-Puccinia producing pycnia and aecia on the alternate host. Also from a taxonomic point of view these questions are important since in the classifications of the rusts proposed by Arthur⁵ and by Sydow⁶ the number of spore forms and the heteroecious or autoecious character are used to determine the generic position of the species of rusts. Without germination of the teliospores the questions could not be answered. It might

⁵ Arthur, J. C. Eine auf die Struktur und Entwicklungsgeschichte begründete Klassifikation der Uredineen. *Résult. Sci. Congr. Bot. Vienne* 1905: 331-348. 1906.

⁶ Sydow, H. Die Verwertung der Verwandtschaftsverhältnisse und des gegenwärtigen Entwicklungsganges zur Umgrenzung der Gattungen bei den Uredineen. *Am. Mycol.* 19: 161-175. 1921. And Weitere Mitteilungen zur Umgrenzen der Gattungen bei den Uredineen. *Ann. Mycol.* 20: 109-125. 1922.

be deduced since *Antirrhinum majus* belongs to the Scrophulariaceae, that the rust would likely be autoecious, judging by other species of *Puccinia* on this and related families. Granting that the germination of teliospores occurs under the cultural conditions used with snapdragon, the absence of aecia, which would not likely be overlooked, points to a brachy-*Puccinia*, the primary uredinia of such a rust being easily mistaken for the uredinia ordinarily found. However, such deductions are erroneous, as is shown by the results obtained. These, taken with those obtained by Hockey, while not actually settling all the questions involved, throw some light on the function of the teliospore in the propagation and life history of the rust.

RESULTS OF STUDY

1918. The first collection of telia used in this study was made on August 10, 1918, from heavily rusted plants near a local greenhouse. Only a small amount of telia was found and these were tied in a coarse cheese cloth bag and hung outside to winter. No test was made for germination until April 24, 1919, when hanging drops of the overwintered spores were made. No germination was noted at this time and on account of the pressure of other culture work no more tests were made that year.

1919. On December 12, 1919, teliospores were found upon old plants of snapdragon in the greenhouse, both dead and green stems. A small amount of teliospores from each was collected and tested for germination in hanging drops on that date. No germination was obtained. Each collection was then overwintered out of doors as before. Hanging drops of the teliospores of each collection were made March 24, April 2, April 15, April 28 and May 11, 1920. On April 15, a very few spores showed germination from the material from green stems. No typical basidia with basidiospores were formed. Some of the teliospores including those in the hanging drop were sown on young rust-free snapdragons, but without obtaining infection. Germination was not obtained in any other tests. It was felt that no conclusions could be drawn from this account of the apparent lack of basidiospore formation.

1920. In the fall of 1920, some very fine material was received from Mr. E. Bethel from Monrovia, California. This consisted of a large number of snapdragon plants bearing abundant teliospores. In addition Mr. Bethel sent a quantity of *Adenostegia filifolia* also bearing plenty of teliospores. The rust on the latter host has been described as a distinct species, but in the North American Flora, Arthur⁷ considers it as belonging to *Puccinia antirrhini*. The material was placed out to winter as before and on December 14, 1920, hanging drops of each showed a very heavy germination, the

⁷ Arthur, J. C. Uredinales. North American Flora 7: 594-5. 1922.

teliospore masses being white with the basidia, and a great abundance of basidiospores was formed. Teliospores from both of these collections, including those from the hanging drops were sown on four young rust-free snapdragons without obtaining infection. On April 4, 1921, the spores were again tested, after having been outdoors all winter, those from snapdragon showed a slight germination, while those from *Adenostegia* showed no germination. Another test April 19, gave no germination in either case.

1921. An attempt to repeat this work was made in 1921. Snapdragons bearing teliospores were obtained in the fall from Professor Blasdale from Berkeley, California. This material was placed out doors to winter as before. It was tested for germination October 18, November 3, November 17, December 3 and December 20, 1921, and January 24, 1922, without showing germination and was in consequence not sown. In addition, in the fall of 1921, a small amount of teliospores was obtained from a local planting. These were brought into the greenhouse and tested for germination November 1, no germination resulting. They were then left on a greenhouse bench until December 13, when a slight amount of germination was noted. However, when sown on young snapdragons they gave no infection.

1922. In the fall of 1922, an abundance of material for culture was obtained from a heavily infected planting at the Experiment Station. A quantity of this was brought into the greenhouse on December 21 and used to mulch 8 pots of young, rust-free snapdragons. The teliospores at that time showed no germination. When tested again on January 24, 1923, they gave a very vigorous germination with abundant basidiospore production. The mulched plants were then placed in an incubation chamber and the humidity brought up to saturation. The germinating spores from the hanging drops as well as some from the mulch were placed on the leaves and stems of the plants. However, no infection was obtained. Volunteer plants which appeared in the field in the spring of 1923 where the rusted snapdragons bearing teliospores had been piled up showed no infection until rusted plants from the greenhouse were set out.

In all the above work the young plants upon which the teliospores were sown were later inoculated with urediniospores of the rust and heavy infection was obtained showing that the plants used were susceptible to the rust. The tests for germination were made in hanging drops left over night at the temperature prevailing in the greenhouse which varied from 10–20° C. The plants were inoculated under these same conditions.

DISCUSSION

The results obtained by Hockey (*l. c.*, 4) and the writer show that the teliospores of *Puccinia antirrhini*, under some conditions at least, are capable of germinating. The results obtained by Peltier and Doran show

that this is not to be expected under all conditions. Doran has suggested the possibility that the teliospores are able to germinate only through a narrow range of temperatures. Since the teliospores tested by the writer were subjected to a variation of temperature, it can not be said that such a possibility is eliminated. However, it seems more likely that conditions to which the teliospores are subjected during and following formation are of more importance. Doran has noted that the amount of teliospore formation in the greenhouse is considerably influenced by the treatment given to the snapdragon plants. It would seem likely that this would also have an influence on their viability. It is interesting to note in this connection that the most vigorous germination of teliospores obtained by the writer was from the maternal having the greatest teliospore formation. Erikson⁸ has noted a somewhat similar situation for teliospores of *Puccinia coronata* f. sp. *Agrostis*. That environmental conditions may have a decided effect on the teliospores themselves is indicated by the observations of Stakman, Kirby and Thiel⁹ who report that in the southern United States teliospores of *Puccinia graminis* are not able to infect barberry. In the case of *Puccinia antirrhini* it is evident that some seasons and in some localities teliospores may be produced in great abundance. Since out of the seven collections made of teliospores of *Puccinia antirrhini* studied at Lafayette, Ind., five gave germination, the teliospores are a factor which must be taken into consideration in connection with the rust of snapdragon.

Although the results obtained by sowing teliospores of the rust are not all that could be desired, negative results never being as satisfactory as positive, nevertheless they furnish some interesting information concerning a number of the questions involved. The lack of infection when germinating teliospores were sown on snapdragon plants indicates that the rust is heteroecious and eliminates them as a source of danger in the spread of the rust unless the alternate host is present. Since all heteroecious rusts produce pycnia and aecia on the alternate host, it must follow that *Puccinia antirrhini* is a long cycled rust, i.e., having all spore forms.

What the aecial host of *Puccinia antirrhini* may be, is an interesting question. The rust does not possess any marked peculiarity of structure or marking which greatly distinguish it from many other species of the genus *Puccinia*. Consequently it is almost a hopeless task to attempt to find the correlated short-cycled *Puccinia* and thus determine the genus of the alternate host.¹⁰ It is very doubtful if the aecial host is to be found throughout

⁸ Eriksson, Jakob. Ueber die Dauer der Keimkraft in den Wintersporen gewisser Rostpilze. Centralblatt. Bakt. Parasitenk. u. Infektionskrankh. 4: 376-388. 1898.

⁹ Stakman, E. C., Kirby, R. S., and Thiel, A. F. The regional occurrence of *Puccinia graminis* on barberry. Phytopathology 11: 39-40. 1921 (Abstract).

¹⁰ For discussion and examples of the use of this method of correlation see Proc. Ind. Acad. Sci. 1921: 133-135. 1 pl. 1922.

the present range of the rust and in consequence attempts to find an association of the stages is likely to be largely wasted effort. All evidence indicates that this rust did not originally occur on snapdragon. *Antirrhinum majus* is a native of the Mediterranean region, but the rust is unknown there. *Puccinia antirrhini* was first discovered by Blasdale¹¹ on cultivated snapdragon at San Leandro, California, in 1896 and was described by Dietel and Holway¹² in 1897 from a collection made by Blasdale at Berkeley, California. Outside of California and Oregon, the rust was not noted until about 1913 when it appeared in a serious way in the vicinity of Chicago, Ill. Since then it has been spread, until it is now found in twenty of the states of the United States, three provinces of Canada and in Bermuda. Apparently, therefore, the rust originated in California, probably from some native species of *Antirrhinum*. Blasdale reports being able to infect *Antirrhinum vagans* Gray with the rust from snapdragon and considers collections of the rust made upon *A. nuttalianum* Benth. and *A. virga* Gray as being *Puccinia antirrhini*. Two other rusts very close to *P. antirrhini* have been described from California, *P. adenostegiae* Arth. on *Adenostegia pilosa* (A. Gray) Green, and *A. rigida* Jepson and *Puccinia cordylanthi* Blasdale on *Adenostegia filifolia* (Nutt.) Abrams (*Cordylanthus filifolius* Nutt.). Blasdale considers each a distinct species, while Arthur has brought them together under the name of *Puccinia antirrhini*. These conclusions were reached without cross inoculations so that it is not certain that *Adenostegia* species are hosts for the snapdragon rust, but they should be kept in mind.

It would seem as if location and observation of the rust on these native species would be the most likely method of obtaining clues as to the aecial host. Apparently the California species of *Antirrhinum* are not abundant and easily accessible. Both the *Antirrhinum*s and *Adenostegia* species are found on dry hills. This, taken with the fact that the teliospores apparently germinate most abundantly soon after maturity, may possibly indicate germination taking place and the infection of the alternate host occurring with the beginning of the fall rains. This also suggests a possibility that the aecial stage is systemic in some winter annual or a perennial in a manner similar to *Puccinia eatoniae* which produces its telia on species of *Eatonia*, the teliospores germinating in the fall, infecting *Ranunculus abortivus*, producing a systemic mycelium from which aecia are formed the next spring.

SUMMARY

1. Germination of the teliospores of *Puccinia antirrhini* has been ob-

¹¹ Blasdale, W. C. A Preliminary List of the Uredinales of California. Univ. Calif. Publ. Bot. 7: 101-157. 1919.

¹² Dietel, P. Einige neue Uredineen. Hedwigia 36: 297-299. 1897.

tained from five out of seven collections studied and during four of the five years tests have been made.

2. Sowings of the germinating teliospores on young, rust-free snapdragons did not give infection in any case.

3. This would indicate that the rust is heteroecious and has pyenia and aecia on an alternate host.

4. It is considered that the most likely method of discovering this host is by observations in California on native species of *Antirrhinum* in localities where they are infected with the rust.

PHYTOPATHOLOGICAL NOTES

Resistance of sorghum to loose and covered smuts.—The writer has carried out an experiment to determine the reaction of certain varieties of sorghum to *Sphacelotheca sorghi* (Link) Clint. and *S. cruenta* (Kühn) Potter. The seed of ten varieties of sorghums were received from Dr. George M. Reed, Brooklyn Botanic Garden, Brooklyn, N. Y., and separate lots inoculated with the spores of the two smuts and sown at Modi Bag Agricultural College, Poona, India.

Five of the varieties used were reported by Reed (Mycologia, **15**: 132-143, May, 1923) as resistant and the remaining five as susceptible to both *Sphacelotheca sorghi* and *S. cruenta* in his experiments. My results are given in the following table:

	<i>Sphacelotheca Sorghi</i>		<i>Sphacelotheca Cruenta</i>	
	No. of heads	Per cent Infected	No. of heads	Per cent Infected
Milo, Dwarf	200*	0	200	0
Milo, Standard	200*	0	200	0
Feterita	370	.2	325	.3
Feterita, Spur	200*	0	200	0
Milo, White ..	200*	0	200	0
Kafir, Sunrise	205	9.2	240	2.05
Kafir, Blackhull	180	18.1	180	4.7
Kafir, Red	165	50.1	307	13.5
Kafir, Dawn	216	40.7	225	23.5
Shallu	140	42.1	178	36.6

* Number of heads estimated.

These results are quite similar to those reported by Reed. The resistant varieties have shown their resistance in my experiments and the susceptible varieties have been more or less severely infected. My earlier reports on the susceptibility of Dwarf Milo (Phytopathology, **11**: 252, 1921) was a mistake due to the fact that the variety used turned out not to be Dwarf Milo.—G. S. KULKARNI.

British Association for the Advancement of Science.—The annual meeting of the British Association for the Advancement of Science in 1924 will take place in Toronto, Canada, from Wednesday, August 6, to Wednesday, August 13. The section in which plant pathologists will be most interested is Section K (Botany), of which Professor V. H. Blackman is the President and F. T. Brooks, 31 Tension Avenue, Cambridge, England, is the Recorder. Professor J. H. Faull and Professor R. B. Thompson, both of the University of Toronto, are chairman and secretary respectively of the local committee for this section. The botanical program is not available at this time but notice has been given of a joint session of the Botany and Zoology Sections on *The Species Concept*. It is hoped that many members of the American Phytopathological Society will plan to attend these meetings.—R. J. HASKEILL.

The May number of Phytopathology was issued May 24, 1924.

PHYTOPATHOLGOY

VOLUME XIV

NUMBER 7

JULY, 1924

APPLE MEASLES, WITH SPECIAL REFERENCE TO THE COM- PARATIVE SUSCEPTIBILITY AND RESISTANCE OF APPLE VARIETIES TO THIS DISEASE IN MISSOURI

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WITH PLATES XVII TO XXI AND ONE FIGURE IN THE TEXT

INTRODUCTION

Since its report and description in Arkansas in 1912, apple measles has been reported from a number of states and appears to be a disease of widespread occurrence that is gradually attracting an increasing amount of attention. This disease, which has been made the subject of two contributions from the Missouri State Fruit Experiment Station (15, 16), is of such common occurrence in the orchards of this station and in those of other sections of the state that the writer began an investigation of it at the beginning of 1923. However, inasmuch as he has accepted another position in a totally different line of investigational work, no further attention can be given this problem. It has been deemed advisable, therefore, to sum up briefly the investigational work thus far done on this disease and to present the work of the writer.

HISTORICAL

Apple measles was first described by Hewitt and Truax (12) from Arkansas in 1912, where it was observed first in 1908. The disease was given the very appropriate name of "measles" and two forms of it were described, namely the pimply or pustular type and the scurfy type. No organism was found which could be definitely considered as the cause of this trouble.

Apple measles was reported next in 1914 by Rose (15), who called it "pimple canker" and states that it had been known at the Missouri State Fruit Experiment Station since about 1904. He describes and illustrates both the pimply and the scurfy types of the disease, calling the latter "scurfy canker" or "rough-bark canker." In the later paper by Rose (16) the rough-bark or scurfy bark type of measles is described in detail and evidence presented that it is caused by one or more forms of bacteria which appear to be the same as the one causing a blister-spot on the fruit of certain varieties of apples.

Adams (1) reports the occurrence of apple measles in Pennsylvania in 1916, giving notes on the same and illustrating the occurrence of this disease on a limb of a Smith Cider tree.

Subsequent reports of apple measles from a number of states are mentioned in several numbers of "The Plant Disease Bulletin" issued by the U. S. Department of Agriculture. Hesler and Haskell (11, p. 18) mention a report that it was local in Pennsylvania and that there the Smith Cider appeared to be the most susceptible variety. They also mention a report from Ohio of a "pimple disease" on apple, which the writer assumes is but another name for measles. Hutchins and Haskell (13, p. 137) state that Leonian reports measles to be common and destructive in New Mexico and that Virginia reported it from Patrick County. Anderson (3, p. 61) states that Leonian reports measles to be quite a serious apple trouble throughout New Mexico. Haskell and Wood (10, p. 51-52) give a resumé of the apple measles situation up to that time. They state that since its first report from Arkansas it has been reported from Pennsylvania, Maryland, Virginia, Alabama, Michigan, Arkansas, New Mexico, Illinois, and Kansas, but neglect to include Missouri. Except for New Mexico they believe the disease to be local and of little importance. The Plant Disease Survey (14, p. 106) mentions a report by Sherwood that apple measles is increasing and apparently causing considerable damage in certain sections of southeastern West Virginia.

Brief reports of the progress of investigations on apple measles in New Mexico occur in the annual reports of the New Mexico Agricultural Experiment Station (4, 5, 6, 7). In the report for 1920-1921 (5) a very comprehensive program of investigational work on this disease is outlined and it is stated that measles has been reported from every apple-growing section in New Mexico, as well as southwestern Texas. It is also reported as occurring in Colorado and South Carolina. A popular account of this disease in New Mexico is given later by Archer (8).

DESCRIPTION OF APPLE MEASLES

Macroscopic description.—The disease known as apple measles is extremely variable in its occurrence. In general it may be stated that there are three more or less distinct types of the disease. As a matter of convenience these may be designated as the isolated pustular type, the aggregate pustular or scurfy type and the canker type. There may be various gradations between the first and the second and, less frequently, between the second and the third of these so-called types, depending somewhat on the stage of development of the disease and the variety affected.

In the isolated pustular type more or less numerous reddish to chestnut brown pustules may occur on the smooth bark of the twigs and young

branches, varying from sparse to dense infestations, as illustrated in plate XVIII, A. This type of the disease has been observed most frequently on York Imperial trees, although the other two types may also occur on this variety. These pustules are generally a light red near the circumference and chestnut brown toward the summit. Superficially they closely resemble fungous pycnidia, but microscopic examination shows the resemblance to be merely superficial. As a rule the pustules average about $1/32$ of an inch in diameter and about half of their diameter in height. Occasionally, as on the limbs of the Family apple tree illustrated in plate XVII, B, they may have a basal diameter of as much as $1/8$ of an inch. The larger pustules at least, due to the unequal tensions arising in the growth of the twig or branch, may split open radially, or they may tend to split basally from the underlying bark, as is shown in plate XVII, B. If a thin shaving be cut from the surface of the cortex with a sharp knife or razor the cut surface is spotted with dark spots according to the number of pustules cut through. As a rule the pustules do not extend inward more than a third of the distance to the cambium, and in no case have they been noted to extend more than about half way in to the cambium.

In certain other phases of the disease the pustules become more numerous and often densely crowded until small areas of the twigs and young branches, or often large areas of the same, have a densely pimply or finely pustular appearance and the whole area of the affected bark becomes irregularly thickened. The thickened bark acquires a darker coloration than the normal bark, becoming reddish brown to blackish and often with a purplish tinge. Occasionally the thickening of the bark is nearly uniform, but usually it is very uneven, giving the appearance of having been formed by the coalescence of a large number of pustules. Some of these nearly uniformly thickened blackish areas of bark often may be confused with a similar type of bark often occurring around blotch infections, but usually are much more extensive and do not exhibit the cracking of the bark with pycnidia as does the blotch. The above type of the disease, which is much more prevalent than the isolated pustular type, may be termed the aggregate pustular or scurfy type since the densely pustular areas of thickened bark give the twigs and branches much the appearance of being covered with a scurf. This is the type of the disease so commonly found on Beach (Plate XVII, A) and Summer Champion trees. On these varieties the pustular thickened areas of bark very frequently have their inception at the nodes, although they also may start at some point along the internodes. After a time the bark that has become densely pustular or scurfy begins to crack and peel off, sometimes in very fine scales, as in Beach, but more often in quite prominent ones, as is shown at the right in plate XIX. Frequently the outer,

densely pustular portion of the bark at the bases of young trees will slough off in heavy scales at an early age (Plate XXI).

Very frequently there occur on the smooth bark of the limbs and trunks of affected trees more or less localized areas of densely pustular bark of the aggregate pustular or scurfy type that soon become roughened and scaly. Owing to the rather sharply demarked limits of these roughened areas of bark they closely resemble cankers and therefore have been designated by the writer as measles cankers. As a rule measles canker formations do not occur on young trees. The case of the heavy bark scaling on the trunk of the tree shown in plate XXI, while morphologically the same as the scaling of the bark on the branches illustrated in plate XIX, is not termed a measles canker because the limits of the affected bark are not sharply defined as are those of the limbs illustrated in plate XIX (in the limb at the right the distal ends of the diseased bark are not shown). As was stated before, however, many gradations are to be found between these arbitrarily determined types. In many varieties the measles canker formation is the only evidence of the disease that the trees exhibit. These cankers usually occur on the branches but sometimes occur at various points on the trunk from the base to the crotch of the scaffold limbs. When occurring at the latter point the cankers usually extend up onto the scaffold limbs. Such mode of infection was noted in Black Annette, Ingram, Iowa Beauty, Isham, Lybyer No. 1, Texas County Seedling, Yellow Transparent, and Wealthy.

The earlier stages of measles canker formation, consisting of densely pustular and irregularly thickened bark areas, or of the same after the pustular layers of the bark have begun to crack, loosen and scale off (Plate XIX, left), are seen much less frequently than the older stages where the outer layer of the pustular bark has become cracked and is in various stages of sloughing off (Plate XIX, right). Where the measles bark has practically all sloughed off the more or less pimply bark usually found at the margins of the bark cankers furnishes the tell-tale signs of measles (Plate XVII, C). However, in other cases where the pustules extend into the bark but very superficially the entire pustular portion of the bark soon sloughs off very completely, leaving behind a smooth layer of bark without even a trace of pustule formation at the margin. This complete exfoliation of the outer diseased bark indicates that the tree has outgrown the disease. This occurs very quickly in small cankers in which the pustules extend into the bark but very superficially, but in those in which the pustules extend in rather deeply the evidence of measles may persist for several years. In the case of an Evans tree the roughened scaling bark of the measles canker still could be seen plainly on a 4½-inch limb. It is very exceptional, however, to find measles cankers still in evidence on limbs of this size inasmuch as the normal processes of bark scaling, which occur sooner or later on the older

stem portions, tend to obscure and obliterate the measles canker formation.

A well illustrated description of the process of bark scaling occurring in the measles cankers has been given by Rose (16), who terms this form of the disease the rough-bark or scurfy-bark canker. He states that these cankers usually are found on the north side of a limb and that, with few exceptions, they are bordered by a pimpled ridge slightly more brown than the healthy bark around them (Plate XVII, C). Rose also states that the active stage of the disease occurs in the early spring and reaches its extreme form on certain varieties of dwarf apples, but that it has been observed on Logan, Munson, Ben Davis, and several others. His description is quoted in the following:

In the development of this active stage, the first change visible from the outside is the formation of narrow cracks, 1.0 to 1.5 mm. deep by 5 to 20 cm. long, about 1 cm. outside of the pimply ridge referred to above. Inside of these cracks the bark is found loosened—as early as March 21, 1916—in a layer about 2 mm. deep. It is easily peeled off and if this be done there is revealed a spongy layer of giant cells about 1 mm. thick, which is white or greenish white at first, but which soon oxidizes to a pale brown and later to a dark brown color. Under natural conditions the loosened outer layer begins to dry and curl slightly within a few days after the cracks are formed; as a consequence the cracks widen, air circulates more freely under the loosened layer and the spongy layer dries down. Within two weeks from the time the cracks first show there is usually no spongy layer to be found and the loosened layer has become dried, curled fragments which break off almost at a touch. Many varieties show no wholesale loosening of the outer bark, but merely a scaling off of small patches without the formation of a definite spongy layer. Sometimes the dry, brown vestiges of such a layer can be found, sometimes not. Possibly in such cases it develops slowly and progressively from one point to another, loosening the bark only a little at a time and drying down almost immediately.

In the numerous measles cankers studied by the writer, however, no such process of bark scaling in which the bark becomes loosened by the formation of a spongy layer of giant cells as described by Rose (15) has been observed. The orchard of dwarf apples for which this process of bark scaling was described and illustrated by Rose was removed a few years ago. The writer is inclined to regard Rose's description of the formation of a spongy layer of giant cells beneath the loosening bark to be analogous to a similar process of bark loosening from an abnormal cell-elongation in the bark parenchyma described by Sorauer (17, pp. 328–331), as a result of the action of a local excess of water. It is not impossible that this pathological condition may have occurred in conjunction with measles. In the many measles cankers studied by the writer the bark scaling resulted only from the formation of cork layers beneath the outer pustular bark.

Measles apparently have their inception only on the fairly young growth, although in the many cases studied by the writer the pustular bark was noted but rarely on the growth of the last year or two, even in very sus-

ceptible varieties. In fact the occurrence of measles on one-year shoots appears very rare, although it has been observed. In the case of larger branches or limbs disposed more or less horizontally there often appears to be a tendency for the measled bark to be confined largely to the upper sides. Both young trees and old ones may exhibit measles and many varieties show unmistakable evidence of having been affected for many years.

Microscopic appearance.—Large numbers of microtome sections were prepared from both imbedded and unimbedded material representing various types of measles in order to study in detail the course of the development of the disease and the pathological anatomy of the diseased bark. In normal apple bark the epidermis is replaced as a tegumentary tissue before the end of the first year by a protective cork layer from 3 to 5 cells deep, which develops from a meristematic layer of phellogen originating on the inner side of the epidermis. This band of cork cells, which represents the primary periderm formation, increases but little in thickness during the course of the next several years, during which it constitutes the external investment of the stem.

In every case observed, where a measles pustule develops this band of cork cells broadens locally, not only as a result of the increase in the number of cells developed beneath the outer layers of cork cells but also as a result of the increased width of these cells as viewed in transverse sections. Like the cells of the protective cork layer normally replacing the epidermis, they are filled with a brown substance which has but little or no affinity for the aniline dyes ordinarily used in staining.

In the fairly distinctly developed pustules there appears to be a rather abrupt transition to still larger and more or less elliptical cells, whose arrangement departs from the radially disposed rows so characteristic of the outermost portion of the bark. The cells at the immediate centers of the individual pustules are thinner-walled than those of the cork layer above; their walls show a strong affinity for cellulose stains, such as Delafield's haematoxylin, and they appear to be parenchymatous in character (Plates XVIII, B; XX, A).

Eventually a layer of cork cells, continuous with the innermost row of cells of the layer of cork replacing the epidermis, develops beneath the tissues of the excrescence, which then become cut off from the underlying cortex. With the continued development of the cork formation beneath the excrescences they tend to become exfoliated.

In the so-called scurfy type of measles, in which the bark becomes so densely pustular that it becomes more or less irregularly thickened over large areas, the general features of pustule formation are essentially the same except that they anastomose more or less extensively and large areas of bark may become involved in the bark exfoliation.

In many varieties, such as the Beach and Summer Champion, the pustules in general always remain characteristically minute and inconspicuous; as a rule they rarely attain the prominence of the one shown in plate XX, A. In other varieties, such as Ingram, Jonathan and York Imperial, in which the pustules as a general rule are characteristically larger and more conspicuous, the layers of cork cells, both above and below the developing pustule, become bowed out by the development of the excrescence, so that in transverse section the smaller types of pustules are lenticular in outline (Plates XVIII, B; XX, A). Or they may enlarge until they become as deep as they are broad and appear more or less circular in outline as viewed in transverse section. In extreme cases of pustule formation, as in the branch

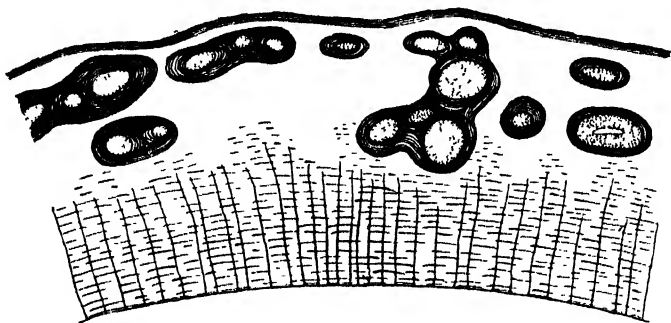


FIG. 1. A semi-diagrammatic camera-lucida drawing of a transverse section through the pustular bark of canker on branch of Jonathan apple tree appearing at left in plate XIX, showing the complete inclusion of old measles pustules, either singly or in groups, in the outer bark and their demarcation from the surrounding cortex by cork layers. The lower shaded portion represents the inner bark or phloem with the medullary rays shown as they actually occurred. $\times 11$.

of the Family apple tree shown in Plate XVII, B, many layers of radially compressed cork cells have developed beneath the original measles pustules so that large and very conspicuous excrescences are formed eventually (Plate XX, B). Here the pustules extend in as far as the outer hard bast bundles.

In still other cases of measles in which the bark has more or less of a lumpy appearance instead of a distinctly pustular one, as in the case of the Jonathan limb shown at the left in plate XIX, large numbers of the pustules often become overgrown in the processes of bark development and remain behind as inclusions in the cortex. These inclusions become walled off from the rest of the surrounding living tissue by a layer of cork developed about them, which is similar to that of the protective layer replacing the epidermis and averages from 10 to 15 cells in thickness (Plate XX, C). Hartig (9) illustrates a similar walling off by cork layers of areas of bark killed by lightning discharge in *Picea excelsa*. In case two or three included

measle pustules closely adjoin one another the wall of cork may develop about the group, dipping inward partially between the individuals (Text figure 1). Many of these inclusions lie near the surface of the bark, while others are more deeply imbedded, being distributed among the outer groups of hard bast fibers. Bundles of bast fibers are often found in the centers of these included tissues.

COMPARATIVE SUSCEPTIBILITY AND RESISTANCE OF APPLE VARIETIES TO MEASLES

We have as yet very meager information concerning the comparative susceptibility and resistance of apple varieties to measles. While Hewitt and Truax (12) give no data on this point, it is evident from their work that Ben Davis, Gano, Givens, Jonathan, and Limbertwig are susceptible varieties. Rose (15) states that the White Winter Pearmain and Beach were severely affected, and that many other varieties also were affected but none of them to any great extent. In his later paper dealing with the scurfy-bark type of measles, Rose (16) states that the disease occurs on such standard varieties as Ben Davis, Jonathan, Logan, White Winter Pearmain, Beach, Stayman Winesap, Munson, and Marsh, but much more severely on certain dwarf varieties. Haskell and Wood (10) state that Pennsylvania reported Smith Cider as the only variety commonly affected, but that Maiden Blush was attacked in 1915. Archer (8) states that the Jonathan seems to be the most susceptible variety in New Mexico, adding that the disease occurs on other varieties but that the damage is negligible. Adams (2) states that measles was reported on Delicious in Kansas in 1922.

At the beginning of 1923 the writer started an intensive reconnaissance study of the several orchards of the Missouri State Fruit Experiment Station in order to determine the extent and severity of apple measles, its forms and mode of occurrence, and to determine the relative susceptibility and resistance of the numerous varieties of apples represented. This reconnaissance was begun during the late winter and was completed before the leaves had begun their development, so that a clear and unobstructed view could be had of all the branches.

The older orchards, represented by the Commercial, East Variety and West Variety Orchards, were studied first. These orchards, which are maintained in sod, were set out in 1902, 1903 and 1904, and replantings made subsequently as the original trees died. A total of 1667 trees was used as a basis for the measles census in these three orchards and many other trees were omitted because there was no record of the variety.

While the paucity of trees of most of the numerous varieties renders it difficult to draw conclusions, it was clearly evident that there are marked

differences in the susceptibility and resistance of different varieties of apples to measles under the same conditions of soil management. It was furthermore evident that many of the susceptible varieties became affected by measles in a manner and extent more or less peculiar to the variety, although some varieties may exhibit all three types of measles. For example, the Beach, Blue Pearmain, King David, Oldenburg, Red Astrachan, Summer Champion, Texas Red, Winter Pearmain, and certain other unknown varieties were characterized by the branches and twigs of many or even all of the trees of some varieties being finely but densely pustular, the pustular condition being of such widespread occurrence that the limbs, branches and twigs appeared scurfy in general. In these varieties the bark on the older limbs eventually becomes finely scaly and measles canker formations rarely occur. In still other varieties, such as the Elkhorn, the measles appearance was the same except that the pustules were larger and more conspicuous. The only Family apple tree present was characterized by unusually large and prominent corky pustules varying from sparse to dense infestations. Some York Imperial and Jonathan trees may show only occasional isolated pustules, while others, or perhaps other branches of the same tree, may show patches of them or scurfy areas of bark, and sometimes canker formations also. The majority of the susceptible varieties, however, merely exhibited measles canker or else occasional pustular patches of the scurfy type on the limbs, or sometimes both. As a rule the measles cankers averaged from 1 to 5 per tree and appeared to be of no consequence in so far as the health of the tree was concerned. However, a few varieties like Heiges, Logan, Munson, and Whitney (crab) proved especially susceptible to this form of measles, the trees commonly having 10, and occasionally as many as 20, cankers on the limbs. As a rule these cankers consisted of long scaly bark areas usually extending entirely around the branches. These cankers were commonly a foot, and sometimes nearly three feet, in length.

It was believed that a reconnaissance of the station's North Commercial and Pruning Orchards, which are divided into a number of different soil management plots, would indicate whether or not any relation exists between soil moisture, fertilization or pruning and the occurrence of apple measles. The North Commercial Orchard was set out in 1921, the soil management plots running at right angles to the variety rows, of which the first four are York Imperial, the next four Willow, the next four Jonathan, the next three Golden Delicious, and the last three Rome Beauty. In 1922 an additional ten trees were interplanted in plots E to J of each variety row for temporary study, making a total of 986 trees in this orchard. Unfortunately for the point to be determined, the York Imperial was practically the only variety that exhibited much in the way of measles. Of a total of 228 trees of this variety 74 exhibited more or less of a measles

appearance, varying from a few pustules on the branches and twigs to a fairly general densely pustular condition of the trunks, branches and twigs. Only 2 of the 228 Willow trees and 3 of the 228 Jonathan trees exhibited a measled condition, and no evidence of this trouble was noted on any of the 155 Golden Delicious and 147 Rome Beauty trees. The number of measled York Imperial trees on any one of the special treatment plots varied within the limits of the number of measled trees on the various check plots and no relation between apple measles and soil management was apparent.

The same situation was found to hold for the Pruning Orchard, which was set in the spring of 1919. This orchard consists of 17 rows of different varieties, with 47 trees in each row except the first (Golden Winesap), which has but 20. Two of the rows were replanted in 1922 to Payne and McIntosh. There is a total of 772 trees in this orchard. The pruning and soil management plots run at right angles to the variety rows. No evidence of measles was noted on any of the trees in the rows of Golden Winesap, Winesap, Paragon, Arkansas Black, Willow, Rome Beauty, Stayman Winesap, Ingram, Black Ben Davis, Payne, and McIntosh. In the remaining rows of 47 trees each the number of trees affected by measles was as follows: Collins, 3; York Imperial, 45; Grimes, 1; Jonathan, 9; King David, 43; Delicious, 8. Here, just as in the North Commercial Orchard, no relation was to be observed between measles and the mode of soil management, nor the mode or severity of pruning. In both these orchards measles appeared to be related only to the variety of the tree and this relation appeared to be a very clean cut one.

The station's Summer Orchard, which is maintained in clean cultivation, was set out in 1919 and originally contained 22 rows of 10 trees each. However, many had died and were replanted in 1920 and 1921. Of the 185 trees used as a basis for the measle census of this orchard the following number of each variety exhibited measles: Yellow Transparent, 5 out of 10; Carson, 1 out of 10; Colton, 1 out of 10; Chenango, 1 out of 8; Summer Champion, 4 out of 9; Wealthy, 2 out of 10. No evidence of measles was noted on the remaining trees, among which were the following: 10 each of Early Harvest, Liveland, Oldenburg, Benoni, Maiden Blush, Red Astrachan, Skelton, Williams, Red June, Eades, and Ada Red; 3 of Lowell; 6 of Wilson June; 3 of Sops-of-wine; and 3 of Fanny.

In the station's Stock and Scion Orchard, which was set out in 1920 and 1921, and which is maintained in clean cultivation, 234 trees were examined. Only one of the Stayman Winesap trees exhibited measles out of the following: 22 each of Virginia Crab, Transcendent Crab, Walbridge, Hibernial, Minkler, Mammoth Black Twig, Henry Clay, Peerless, and Lilly; 8 Ingram; 7 Stayman Winesap; 7 Grimes; and 14 Mann.

In the station's Top-worked Orchard, which is maintained in sod, but

little of any general interest on measles was noted. The portion remaining at the time of the reconnaissance consisted largely of Ben Davis-Jonathan crosses, unknown varieties and trees top-worked with one or more varieties. Among the latter one tree top-worked with Matt Seedling and one with Reinette Clermontois exhibited measles cankers on the limbs. Another tree top-worked with Cox Orange below and Arlington above exhibited numerous large measles pustules on the limbs and branches, and smaller ones on the twigs practically throughout the entire tree, with the bark becoming finely scaly on many limbs.

Two test orchards of seedling trees, most of which had come into bearing, also were examined and many trees were found to exhibit measles in varying degrees. These trees were crosses between various varieties, but mostly between Ben Davis and Jonathan. Of the unnamed chance seedling trees in the orchards of the station 7 out of 21 seedlings representing 30 trees were affected by measles in varying degrees.

The reconnaissance of the young orchards affords additional strength for the opinion formulated from that of the old orchards that there are marked differences in the susceptibility and resistance of different varieties of apples to measles under the same conditions of soil and management. Tree age does not appear to be a determining factor in the occurrence of measles for in many of the varieties both young and old trees exhibited the trouble, and many of the latter clearly have been affected for several years. However, in a few varieties, namely Arkansas Black, Black Ben Davis, Hibernial, Minkler, Oldenburg, Red June, Skelton, Tolman, Wealthy, Williams, Wilson June, Winesap, and Winter Paradise, measles was noted on the old trees but not in the young ones.

In table 1 a list of all the known varieties of apples in the orchards of the Missouri State Fruit Experiment Station exhibiting measles is given, the character of the disease exhibited being classified into two more or less broad types, namely the pustular type, covering all gradations between the closely allied isolated pustular type and the aggregate pustular or scurfy type, and the canker type. In case the trees of any one variety exhibited both of these types of measles an asterisk is placed in each column and the type predominating, if either, marked with two asterisks.

It is not claimed that the varieties in the list below are not susceptible to measles because the number of trees of practically all of them is far too small to justify this conclusion. In the field reconnaissance it was noted that a few varieties that did not exhibit measles in one orchard did in another. Further studies of trees of the varieties in this list will undoubtedly show that several of them are susceptible to measles. In fact, of the varieties listed in table 2, two have been reported to be affected by measles, namely the Limbertwig in Arkansas, by Hewitt and Truax (12), and the

TABLE 1.—*Varieties of apples in orchards of Missouri State Fruit Experiment Station exhibiting measles.*¹

Variety of tree	Number Present	Number Affected	Type of measles exhibited	
			Pustular type	Canker type
Akin	1	1	*	
Alexander	2	2	*	**
Arkansas	8	4		*
Arkansas Black	50	3		*
Arlington (topworked)	1	1	*	
Ashton	1	1		*
Autumn Cranberry	2	1		*
Autumn Sweet Swaar	2	2		*
Babbitt	2	2	*	**
Baker	2	2		*
Baxter	3	2		*
Beach	19	19	*	
Belmont	2	2		
Ben Davis	75	14		*
Ben Hur	4	2		*
Bentley	2	2		*
Black Annette	2	2		*
Black Ben Davis	67	10		*
Blue Pearmain	2	2	*	
Bonum	2	2		*
Boskoop	1	1		*
Bryan	3	1	*	
Buckingham	4	2		*
Buncombe	3	3		*
Calvert	2	1	*	
Carson	10	1		*
Chase Blush (crab)	2	1		*
Chenango	15	1	*	
Cleopatra	2	2		*
Coffelt	1	1		*
Coffman	3	1		*
Collins	118	16	*	**
Colton	15	2	*	*
Cox Orange (topworked)	1	1	*	
Delicious	62	10	*	
Early May	3	3	*	**
Early Melon	2	1		*
Elkhorn	3	3	*	
English Russet	4	3		*

¹ The nomenclature for apple varieties here listed is that of Beach (The Apples of New York, Volumes I and II, Ann. Rept. N. Y. (State) Agr. Exp. Sta., 1903, 1905) and Regan (Nomenclature of the Apple; a catalogue of the known varieties referred to in American publications from 1804 to 1904, U. S. Dept. Agr., Bur. Plant Ind. Bul. 56, 1905). A few varieties not found in these publications are of foreign origin or American varieties that at present are not grown to any extent commercially.

TABLE 1.—(Continued.)

Variety of tree	Number Present	Number Affected	Type of measles exhibited	
			Pustular type	Canker type
Esopus	6	2	*	*
Evans	4	2		*
Excelsior (crab)	1	1		*
Fall Pippin	5	2		*
Fall Queen	1	1		*
Fall Stripe	2	2		*
Family	1	1	*	
Gano	4	1		*
Garden Seedling	6	6		*
Gilpin	8	1		*
Givens	45	27	*	**
Gladstone	2	2		*
Golden Russet	2	2		*
Gravenstein	4	3		*
Green Sweet	1	1		*
Grimes	75	1	*	
Hawley	2	2		*
Hargrove	3	3	*	
Hastings Red	1	1		*
Heiges	38	38	*	**
Hibernal	25	3		*
Highfill	5	3		*
Hightop Sweet	3	2		*
Holbert	3	1		*
Holley	1	1		*
Holman	3	3		*
Holt	11	2	*	**
Hoover	4	4		*
Hubbardston	1	1		*
Hurue	5	1		*
Hyslop (crab)	4	2		*
Ingram	126	16	*	**
Iowa Beauty	1	1		*
Isham	2	1		*
Ishewood	3	3		*
Ishmaelite	2	2	*	*
Jacob	1	1	*	
Jersey Sweet	3	2		*
Johnsonite	1	1		*
Jonathan	372	37	*	**
Kentucky Red (crab)	3	1		*
King	6	1		*
King David	52	48	*	
Kinnard	12	2	*	*
Kittageskee	3	2	*	
Kooroochiang (U. S. D. A. buds)	2	1		*
Langford	3	3		*
Lansingburg	8	2		*
Lawver	5	2		*

TABLE 1.—(Continued.)

Variety of tree	Number Present	Number Affected	Type of measles exhibited	
			Pustular type	Canker type
Logan	11	10		*
Loy	5	3		*
Lybber No. 1 (Seedling from Dykes, Mo.)	7	3		*
Lybber No. 2 (Seedling from Dykes, Mo.)	2	1		*
Malinda	6	3		*
Mamma	3	2		*
Margaret	3	1		*
Marsh	3	3	*	**
Martin	3	3		*
Matt Seedling (topworked)	3	1		*
Maxon's Early	2	1	*	
Milam	2	2		*
Minkler	41	6		*
Mock	2	1	*	*
Monsees	5	1		*
Moore's Black	2	1		*
Mother	22	5	*	*
Munson	2	2		*
McAfee	5	2		*
McMahon White	2	1		*
Neuer Englisher Pigeon	1	1		*
Nickajack	6	3		*
Nixonite	5	1		*
Nordhaussan	3	1		*
Northern Spy	4	1		*
Northwestern Greening	4	1		*
Ohio Nonpareil	2	2		*
Oldenburg	14	4	**	*
Ontario	1	1		*
Ozone	17	1	*	
Pennoek	2	1		*
Pewaukee	3	3		*
Pilot	3	2		*
Plumb Cider	3	1		*
Popoff	2	1		*
Porter	2	2		*
Powers	2	2	*	
Price Sweet	1	1		*
Quaker Beauty	1	1		*
Queen	2	2		*
Balls	9	5		*
Rambo	9	1	*	
Red Astrachan	16	5	*	
Red Belle Fleur	1	1		*
Red June	11	1	*	*
Reinette Clermontois (topworked)	2	1		*
Roxbury	1	1		*
Salome	4	1		*
Sandbrook	2	2	*	

TABLE 1.—(Continued.)

Variety of tree	Number Present	Number Affected	Type of measles exhibited	
			Pustular type	Canker type
San Jacinto .	4	2		*
Schroeder .	1	1		*
Shannon .	2	2		*
Shannon Improved	12	2		*
Sharp's Nonesuch (U. S. D. A. buds)	1	1	*	*
Shirley .	6	2	*	*
Skelton .	16	3		*
Smith Cider .	2	2	*	
Stayman Winesap	58	4	*	**
St. Lawrence	2	1		*
St. Louis .	8	3		*
Summer Champion	21	16	*	
Summer Rambo	1	1	*	*
Sweet Pear	1	1		*
Tanhaki (U. S. D. A. buds)	2	2	*	
Texas County Seedling (from Texas Co., Mo.)	62	31	**	*
Texas Red	2	2	*	
Tolman .	14	5	*	*
Tunnell	2	1		*
Twenty Ounce	2	1		*
Utter	2	2		*
Victuals and Drink	2	2		*
Wandering Spy .	2	1		*
Wealthy	13	3	*	**
Western Beauty	1	1		*
West Plains Seedling (from West Plains, Mo.)	6	2		*
Whitney (crab)	6	5		*
Williamis	15	1	*	
Willow	279	2	*	
Wilson June	11	2		*
Winesap	64	7		*
Winter Paradise	12	2		*
Winter Pearmain	2	2		*
Wolf River	6	3		*
Yellow Horse .	3	1		*
Yellow Newtown	6	4	*	
Yellow Transparent	14	6	*	**
Yarra Bank (U. S. D. A. buds)	1	1	*	
Yates	6	6	*	*
York Imperial	338	147	**	*
Total	2656	763		

Maiden Blush in Pennsylvania, by Haskell and Wood (10). With these two changes in mind, the lists given in these two tables should prove valuable as temporary check lists in future studies of this disease. In general it may be said that Gold, Grimes, Oliver, and the majority of the true crab apples appear to be very resistant to measles.

TABLE 2.—*Varieties of apples in orchards of Missouri State Fruit Experiment Station not exhibiting measles.*

Variety of tree	Number Present	Variety of tree	Number Present
Ada Red	10	Giant Jeniton	1
Albermarle	1	Gideon	3
Alexis (crab)	1	Gloria Mundi	5
Anoka apple (crab)	3	Gold	19
Amur (crab)	2	Golden Delicious	155
Baldwin	5	Golden Queen	4
Banana	5	Golden Sweet	1
Benoni	12	Golden Winesap	20
Bietingheimer	3	Greenville	7
Bismarck	2	Grindstone	1
Black Burgess	1	Haas	2
Black Oxford	3	Henry Clay	24
Black Warrior	3	Herkimer	1
Bledsoe	2	Higgin Botham (seedling from	
Blood Red	3	Olden, Mo.)	2
Boiken	2	Hopa Red-flower Crab	1
Broome	1	Horn	5
Burk	1	Howard Sweet	2
Capitola	2	Imperial Rambo	1
Carolina Greening	1	Irish Peach	1
Carolina Watson	1	Jefferis	2
Carter Blue	1	John Sharp (U. S. D. A. buds No.	
Cathay (crab)	2	21722)	1
Chance	1	Kaump	3
Chicago	5	Lady Sweet	4
Cliff Seedling (U. S. D. A. buds)	1	Lilly	25
Clinton	1	Limbirtwig	2
Cooper Market	3	Liveland	10
Cornell	1	Longfield	3
Danvers	1	Lowell	7
Dees No. 2 (seedling from Arkansas)	2	Lyhyer No. 3 (seedling from Dykes,	
De Verike	1	Mo.)	1
Dolgo (crab)	3	Magg's Seedling (U. S. D. A. buds)	1
Domine	2	Maiden Blush	13
Duling	1	Mammoth Black Twig	22
Eades	10	Mammoth Grimes	2
Early Harvest	12	Mangum	3
Early Ripe	1	Mann	18
Estalline	2	Martha	2
Fallawater	1	Matthews	2
Fall Winesap	3	May Pippin	1
Fanny	9	Milwaukce	3
Fletcher	1	Montgomery	1
Florence (crab)	7	Missouri (crab)	2
Fulton	5	Missouri Wild Crab	3
General Grant (crab)	1	Montral Beauty (crab)	1

TABLE 2—(Continued)

Variety of tree	Number Present	Variety of tree	Number Present
McIntosh	54	Scott Winter	3
Nocalyx Crab	1	Shockley	1
Odessa (crab)	3	Simmons Red	3
Olga (crab)	1	Smokehouse	1
Oliver	20	Sops-of-wine	5
Paradise Sweet	1	Soulard (crab)	3
Page (crab)	2	Springdale	1
Paragon	47	Stark	3
Patten	4	Starr	1
Payne	52	Steele Red	1
Pock	1	Striped Pippin	1
Peerless	25	Summer Pearmain	2
Peter	3	Summer Queen	2
Pine Stump	2	Sweet Bough	8
Poorhouse	2	Takapuna	1
Pound Sweet	3	Tippin Seedling (from G. T. Tippin, Springfield, Mo.)	6
Primate	2	Trader	2
Princess Sweet	1	Transcendent (crab)	26
Pumpkin Sweet	3	Ulster	1
Quaker (crab)	1	University	1
Quince (of Cole)	3	U. S. D. A. No. 37568	1
Ramsdell Sweet	3	U. S. D. A. No. 37717	1
Raspberry	3	U. S. D. A. No. 37849	1
Red Siberian (crab)	6	U. S. D. A. No. 38102	1
Red Tip Crab	2	Vandevere	3
Reinette de Besins	1	Van Wyck (crab)	3
Rensselaer	1	Virginia (crab)	25
Rhode Island (Greening)	2	Wagener	4
Ripen de Loudies	1	Wallace Howard	1
Robinson	2	Walbridge	24
Rolfe	4	Westchester	1
Rome Beauty	200	White Pippin	2
Rome (Illinois Red)	2	Winterstein	1
Rome (Ohio Dark Red)	2	Yellow Bell	2
Ronge de Nieman	1	Yellow Bellflower	3
Royal Limbertwig	2	Yellow Siberian (crab)	4
Ruby Pearmain	1	York Stripe	3
Rutherford	8		
Rutledge	1		
Saratoga	1	Total	1155
Schoharie	1		

THE CAUSE OF APPLE MEASLES

While a number of widely differing opinions have been advanced to explain the cause of apple measles, no satisfactory and convincing explana-

tion has yet been made and substantiated. Some think bacteria are responsible for it; others suggest unfavorable soil conditions, while still others advance the theory of physiological disturbance. However, there is but scanty experimental data supporting any of these theories.

Hewitt and Truax (12), whose attempts to isolate a fungus or bacterial organism resulted negatively, were of the opinion that apple measles is wholly a physiological trouble. The only inference of a cause with any apparent basis was the possibility that it might be an abnormal lenticel development in which the lenticels, when forming, become diverted from their normal development in such a fashion that layer after layer of cork is formed instead of the ordinary spongy tissue with only occasional corky layers. They regard this inference as supported by the apparent relation between the relative number of lenticels and pustules, the number of lenticels appearing to decrease as the number of pustules increases. As a basis for this relation they present the counts of the lenticels and pustules on one-foot lengths of 45 branches ranging from $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter and representing relatively mild cases of the isolated pustular type of measles on four varieties, namely Ben Davis, Gano, Givens, and Jonathan.

Rose's paper (16), in which the rough-bark or scurfy-bark type of measles is described in detail and in which evidence is presented that this disease is caused by one or two forms of bacteria which appeared to be the same as the one causing a blister-spot on the fruit of certain varieties of apples, seems to have been overlooked by most workers on apple measles. He isolated from various parts of the roughened bark a bacterial organism, very similar morphologically to the blister-spot organism but which upon further study appeared to consist of two different organisms or possibly of two closely related but distinct varieties. One of them, represented by five strains, showed great similarity in morphological and cultural characteristics to the blister-spot organism; the other, represented by 15 strains, resembled the blister-spot morphologically but differed from it in cultural characteristics. Inoculation of bark with the latter organism or variety of organism, which liquefied gelatine rapidly, produced swollen spots 1 to 2 mm. high and covering an area of roughly 1 sq. cm. At these swellings the typical signs of the disease were reproduced, in miniature, and an organism was recovered which agreed in cultural and morphological characteristics with the one used for inoculation. Typical blister spots on the fruit were produced by inoculating Jonathan and Early Melon apples with both bark organisms and these in turn were recovered from the lesions produced. Rose concludes that the cultural characteristics of the blister-spot organism and the two bark organisms suggest that the differences between them are differences of degree rather than of kind and that all three are possibly merely varieties of one species. He believes that more work is necessary,

however, before the true relationship between the fruit disease and the bark disease can be established.

Adams (1), whose material was associated with trees growing in damp ground or under poor drainage conditions, contrasts the theory of Hewitt and Truax (12) with that advanced by Sorauer (17) to explain the tan disease, and suggests that the conditions favoring these diseases may be the same but that the symptoms manifested may depend upon the parts affected.

According to Haskell and Wood (10), Leonian in New Mexico attributed the disease to an excess of nitrates in the soil, while Coons in Michigan believed it to be due to insect injury to young twigs. They suggest, however, that what is being called measles in various states may be a trouble resulting from various causes. Leonian is quoted by Hutchins and Haskell (13) as stating that the spots in which affected trees grow enlarge from year to year, forming circular areas where only a few plants can grow and the trees invariably become measled. It is stated that soil from these spots, upon analysis, showed the presence of nitrates and carbonates in such large amounts as to be positively injurious to the growing things. Essentially the same account of measles is given in the 30th Annual Report of the New Mexico Agricultural Experiment Station (4), in which it is stated that samples from these spots showed their nitrate content to be as high as two thousand parts in the million and that this large amount of nitrates was believed to be the cause of measles.

In the later reports of the New Mexico Agricultural Experiment Station (6, 7) it is stated that experiments in the laboratory to culture and isolate an organism that might be responsible for apple measles have given negative results. In the latest report of this station (7) it is stated that field work, including inoculations of various types into healthy tissue and various types of grafting, have all failed to show characteristic behavior of parasitic organisms. It is further stated that considerable difficulty has been encountered when trying to use measled wood as stocks, as this wood seems to have but little vitality.

The writer likewise has attempted to isolate a causal organism from the pustular and scurfy types of measled apple bark. For this work he was fortunate in having the assistance of Miss Beatrice White, who previously assisted Dr. Rose in his work (15, 16) at this station. In some cases no organism was secured; in others mixed cultures of bacteria were secured, which were separated in poured plate cultures with the hope that the form or forms described by Rose (16) might be found. In this, however, the writer was disappointed, and before other attempts could be made it became necessary to abandon the work. In fact the writer was even unable to find in the orchards the blister spot disease of apples described by Rose. Examination of numerous sectional preparations of carefully imbedded

material stained in various ways never revealed any mycelium or bacteria within the cells.

The writer has not had the opportunity to conduct a series of experiments designed to determine whether or not measles can be transmitted by grafting. However, a large number of apple grafts made at this station during the winter of 1922-23 were inspected with the hope of finding some of especially susceptible varieties in which the scions might have been taken from measled branches. In this the writer was fortunate for he found two young trees of Summer Champion and five of Beach, the scions for all having been cut from densely measled branches. In one of the Summer Champion trees the bark at the base of the new growth was distinctly measled but no evidence of measles was noted on any of the other trees. Even this single case of the new growth being affected, however, does not necessarily prove that the disease is transmissible for it may have arisen on the new growth from the same cause that induced its development on the trees from which the scions were taken.

The investigations of the writer do not indicate that apple measles is caused by an excessive amount of nitrates in the soil, nor by excessively wet or poorly drained soils. This disease occurs in all the apple orchards of the Missouri State Fruit Experiment Station, including both young and old. It occurs on the well-drained sites as well as on the poorly drained ones, and in both orchards maintained in sod and in clean cultivation. It likewise occurs more or less throughout the apple orchards of the state.

While the writer has observed no relation between the drainage of the soil, the application of fertilizers, tillage and cover crops, or the method of pruning and the prevalence of apple measles, it has been noted that certain varieties of apple trees are peculiarly subject to the disease while others growing under the same conditions appear to be more or less immune to it. The disease known as apple measles has not been reported on any other tree and apparently is peculiar to the apple.

While apple measles clearly is a reaction of the bark to internal disturbances of the equilibrium, it still remains to be demonstrated whether this trouble is caused by some fungous or bacterial organism or by some purely physiological derangement of the normal processes of growth and possibly also of nutrition. That this trouble is not caused by a fungus appears to be reasonably certain. The possible rôle of bacteria as a causal agent appears to be in doubt, the work of Rose being contradictory to that of all others who have investigated this disease. The writer is inclined to regard the trouble as a physiological one.

RELATION OF MEASLES TO THE HEALTH OF THE TREE

The statements in regard to the relation of measles to the health of the tree are also quite contradictory in the different localities from which the

disease has been reported. Hewitt and Truax (12) state that, while but few cases had been found where it could be stated with reasonable certainty that the disease had killed the tree, in nearly all cases the vitality of the tree had been noticeably impaired and in many cases limbs had died apparently as the result of this trouble alone.

The following statements by Rose (15) are of interest in this connection:

The disease does not work as rapidly as Illinois canker on apple or blight on pear but it does seem, in time, to kill out susceptible varieties. All of the White Winter Pearmain trees in the Station orchard were killed about ten years ago under conditions which indicated pimple canker as the only cause of their death. At present all trees of the Beach variety—Apple of Commerce—are affected. They do not seem to be particularly unhealthy so far as fruit and foliage are concerned but others of this variety have died after several years of attack by the disease. Many other varieties are affected but none of them to any great extent.

In his later paper dealing with the scurfy-bark type of apple measles, Rose (16) says:

Affected trees are not quickly killed as in the case of Illinois canker . . . but there is no doubt that the peeling off of fresh layers of bark every spring is definitely injurious to the tree, aside from the opportunity given for entrance of canker fungi and various bark insects.

Hutchins and Haskell (13) quote Leonian as reporting from New Mexico that trees affected by measles remain stunted for years and eventually die; also that spots in which affected trees grow enlarge from year to year, forming circular areas where only a few plants can grow and the trees invariably become measled. Essentially the same account is given in the 30th Annual Report of the New Mexico Agricultural Experiment Station (4). In the 32nd Annual Report of this Station (5) it is stated that the affected trees remain dwarfed and that the fruit which they bear is small in size and inferior in quality. It is stated further here that affected trees may linger for years until they die, but that when once seriously affected they cease to have any commercial value. In a later account of apple measles in New Mexico, Archer (8) makes the following statements in regard to the relation of this disease to the health of the tree:

There is yet no absolute proof that the "Measles" actually kills trees. It is certain that the disease does weaken them so that other pests can attack and kill them. Badly affected trees do not thrive well. Their growth is much reduced, so that they remain dwarfed. Such trees bear but little fruit and this of inferior quality. Seriously affected trees may linger along for years but at their best they are of little or no value.

The writer's observations, which were based upon a large number of

affected trees and varieties, do not indicate that the disease known as measles is responsible for more or less of a rapid decline of the tree as a rule. There does not appear to be any indication of either the dying or the decline of any of the 19 Beach or of the 2 Winter Pearmain trees remaining in the station orchards, although these varieties have long been severely affected and a serious loss of them about 1904 was attributed to measles by Rose (15). Many other varieties, such as the Blue Pearmain, King David, Oldenburg, Red Astrachan, Summer Champion, Texas Red, and one unknown variety bought for Oldenburg, also have exhibited a heavily measled appearance for several years, the bark of practically all the branches and twigs being more or less densely pustular, and yet these trees show no indication of dying, dwarfing, unproductiveness, or even of diminished vigor. In the great majority of the varieties herein recorded as being affected by measles, especially in the majority of those listed as having from one to several rough-bark or canker formations, it is clearly evident that the disease is of practically no consequence is so far as the health of the tree is concerned and that the affected trees ultimately outgrow the disease in many cases.

It is not denied, however, that especially susceptible varieties of trees may not be killed by measles. In the case of the two Munson trees and one each of the Lybyer No. 1 and Texas County seedling trees in the station's West Variety Orchard some of the severely affected branches were dying apparently as a result of measles. The sickly condition of a Colton tree set in 1920 in the Summer Orchard is likewise believed to be due to measles. Of the many measled trees observed by the writer, however, these are the only cases where any dying of the tree or part of the tree was believed to be due to measles, and in some instances attacks by weakly parasitic fungi appeared to be a factor in their decline.

On the other hand, many young and vigorously growing trees appear to be able to overcome the trouble, for several Ingram, Mother and York Imperial trees set in 1918 clearly were heavily measled on the trunk at an early age and yet appeared to have largely outgrown the trouble without any special treatment. It is believed that any method of orchard management that will promote a good, vigorous growth of the trees will prove valuable in controlling apple measles.

SUMMARY

This paper discusses an obscure bark disease of apple trees, which has been variously termed measles, pimple canker, rough- or scurfy-bark canker, and pimple cancer. This disease was reported and described originally in 1912 from Arkansas, where it was observed first in 1908. In 1914 it was reported from Missouri, where it is claimed to have been known since about

1904. Since these reports apple measles, which is gradually attracting an increasing amount of attention, has been reported from Michigan, Ohio, Pennsylvania, Maryland, West Virginia, Virginia, South Carolina, Alabama, Illinois, Kansas, Colorado, Texas, and New Mexico.

The literature on apple measles, which has been brought together for the first time, has been reviewed and discussed, and descriptions are given of both the macroscopic and microscopic characters of the disease. In addition the results of the writer's observations on the comparative susceptibility and resistance of apple varieties to measles in Missouri, the relation of this disease to the health of the tree and its cause are given.

A total of 3811 trees of known varieties and named seedlings was used as a numerical basis for this study. In addition to these trees many trees of unknown variety and several hundred seedling trees, mostly of Ben Davis-Jonathan crosses, were examined. Of a total of 347 known varieties and named seedlings of apple trees in the orchards of the Missouri State Fruit Experiment Station, including the youngest as well as the older trees, 177, or 51 per cent, exhibited measles to a greater or less degree, but mostly of the canker type. Of the 2656 trees comprising the known varieties exhibiting measles 763, or 28 per cent, were affected.

There are marked differences in the susceptibility and resistance of different varieties of apples to measles, certain ones being conspicuously susceptible while others are equally resistant under the same conditions of soil and management. Many of the susceptible varieties become affected by measles in a manner and extent more or less peculiar to the variety. Some varieties, however, like the York Imperial, may exhibit a number of different forms of the disease. Only a comparatively few varieties appear to be markedly susceptible to measles. Among these may be mentioned Beach, Blue Pearmain, King David, Oldenburg, Red Astrachan, Summer Champion, Texas Red, Winter Pearmain, and certain unknown varieties for the scurfy type of the disease, and Heiges, Logan, Munson, and Whitney (crab) for the canker type of the disease. Young York Imperial trees are likewise very susceptible to measles, although the older ones exhibit it less frequently. Of other well known varieties Jonathan appears to be much less susceptible than the York Imperial, and Ingram still less so, while Ben Davis appears to be only slightly susceptible. Among the varieties that appear quite resistant may be mentioned Gold, Grimes, Oliver, and the true crab apples in general.

The several explanations that have been advanced to explain the cause of apple measles in a number of the states from which it has been reported are diverse and contradictory. In Missouri the writer has found no relation between drainage of the soil, the application of fertilizers, tillage and cover crops, or the method of pruning and the prevalence of apple measles. While

this disease clearly is a reaction of the bark to internal disturbances of the equilibrium, the causal agent is still in doubt. The trouble does not appear to be caused by any organism, either fungous or bacterial, but appears to be purely a physiological one.

The statements that have been made in regard to the relation of apple measles to the health of the tree are also quite contradictory in the different localities from which the disease has been reported. The writer's observations of the disease in Missouri do not indicate that it is responsible for more or less of a rapid decline of the tree as a rule. He has observed numerous trees of several varieties which have exhibited a heavily measlesed appearance for several years and yet show no indication of dying, dwarfing and unproductiveness, or even of diminished vigor, as has been reported for trees affected with measles in some localities. Only in a very few cases observed by the writer has a sickly condition of the tree or the dying of the branches been attributed to measles. In the orchards studied by the writer, measles, as a general rule, do not appear to be of any great consequence in so far as the health of the tree is concerned. Many young and vigorous trees ultimately outgrow the trouble without any special treatment.

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LITERATURE CITED

1. ADAMS, J. F. Notes on plant diseases in Pennsylvania for 1916. Ann. Rept. Pennsylvania State College, 1916-1917: 329-336. *Fig. 2-4, 6-12.* 1919.
2. ———. Diseases of fruit and nut crops in the United States in 1922. U. S. Plant Disease Bulletin. Supple. 28: 267-392. *Fig. 58-103.* 1923. [Mimeographed.]
3. ANDERSON, H. W. Diseases of fruit crops in the United States in 1920. The Plant Disease Bulletin. Supple. 14. 114 p., 19 fig. [Mimeographed.]
4. ANONYMOUS. Apple measles. 30th Ann. Rept. New Mexico Agric. Exp. Sta., 1918-1919: 18.
5. ———. Apple measles. 32nd Ann. Rept. New Mexico Agric. Exp. Sta., 1920-1921: 16-19.
6. ———. Apple measles. 33rd Ann. Rept. New Mexico Agric. Exp. Sta., 1921-1922: 13-14.
7. ———. Apple measles. 34th Ann. Rept. New Mexico Agric. Exp. Sta., 1922-1923: 17-18.
8. ARCHER, W. A. Apple "measles" or pimple cancer. New Mexico Agric. Exp. Sta. Press Bull. 397. 1 sheet. 1921. [Mimeographed]; also in Organized Farming (New Mexico Agric. Exp. Sta.), 2: no. 9, p. 15. Aug., 1921.
9. HARTIG, ROBERT. Neue Beobachtungen über Blitzbeschädigung der Bäume. Centralbl. f. Ges. Forst. 25: 360-381, *fig. 47-71*; 523-544, *fig. 81-110.* 1899.
10. HASKELL, R. J., and JESSIE I. WOOD. Diseases of fruit and nut crops in the United States in 1921. United States Dept. Agric. Bur. Plant Ind. Plant Disease Bull. Supple. 20. 138 p., 26 fig. 1922. [Mimeographed.]

11. HESLER, L. R., and R. J. HASKELL. Summary of plant diseases in the United States in 1918—Diseases of fruit crops. The Plant Disease Bulletin. Supple. 1: 1-41. 1919. [Mimeographed.]
12. HEWITT, J. L., and H. E. TRUAX. An unknown apple tree disease. Arkansas Agric. Exp. Sta. Bull. 112, pp. 481-491, 14 figs. 1912.
13. HUTCHINS, L. M., and R. J. HASKELL. Diseases of fruit crops in the United States in 1919. United States Dept. Agric. Bur. Plant Ind. Plant Disease Bulletin. Supple. 9: 82-179. Fig. 23-29. 1920. [Mimeographed.]
14. Plant Disease Survey. The Plant Disease Bulletin 6: 100-114. 1922. [Mimeographed.]
15. ROSE, D. H. Report of pathologist. Pimple canker. Bienn. Rept. Missouri State Fruit Exp. Sta., 1913-1914 (Bul. 24): 29-30. Pl. 6 (figs. 2-3). 1914.
16. ROSE, D. H. Blister spot of apples and its relation to a disease of apple bark. Phytopath. 7: 198-208, fig. 1-3. 1917.
17. SORAUER, PAUL. Manual of plant diseases. Volume 1. Non-parasitic diseases. 3rd Ed. 908 p., 208 fig. English translation by Frances Dorrance.

EXPLANATION OF PLATES*

PLATE XVII

A.—Measled branches of Beach apple tree, showing the finely pustular condition of the bark characteristic of this and certain other varieties when affected by this disease. The disease has its inception as small pustular patches which commonly, although by no means always, start at the nodes. Natural size.

B.—Pustular type of measles on branch of Family apple tree with unusually large pustules. Natural size.

C.—Portion of measles canker on branch of White Transparent (dwarf) apple tree, showing pimply margin of the roughened scaly bark area. Natural size. (After Rose.)

PLATE XVIII

A.—Pustular type of measles on twigs of York Imperial apple tree set in 1919, showing unusually large pustules varying in occurrence from sparse to dense. $\times 2$.

B.—Transverse section through ruptured measles pustule on one of the twigs illustrated in A, showing the formation of a cork layer beneath the tissues of the pustule. $\times 90$.

PLATE XIX

Two measles cankers that occurred on the same branch of a Jonathan apple tree. The younger canker at the left shows an irregularly thickened, densely pustular condition of the bark, which is just beginning to scale off. On the older canker at the right, the distal ends of which are not shown, evidence of the irregularly thickened densely pustular outer bark can still be seen, although most of it has become loosened and broken up into pieces of various sizes, which are beginning to be exfoliated. Natural size.

PLATE XX

A.—Transverse section through measles pustule on one of the York Imperial twigs illustrated in Plate II, A, showing the formation of a cork layer beneath the tissues of the pustule. $\times 105$.

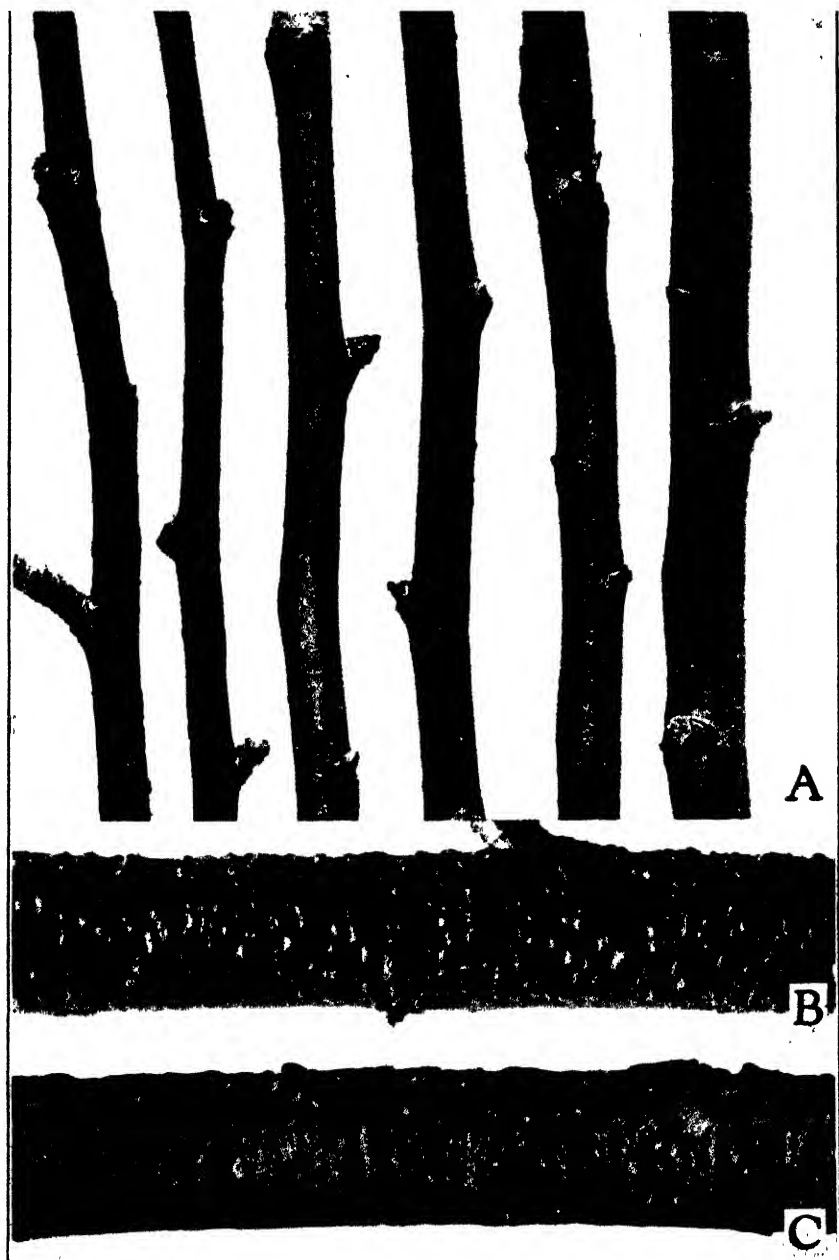
*All photographs, with the exception of Plate I, C, are by the writer.

B.—Transverse section through half of a large corky pustule on the branch of the Family apple tree illustrated in Plate I, B, showing the many corky layers developed beneath the original pustule. $\times 80$.

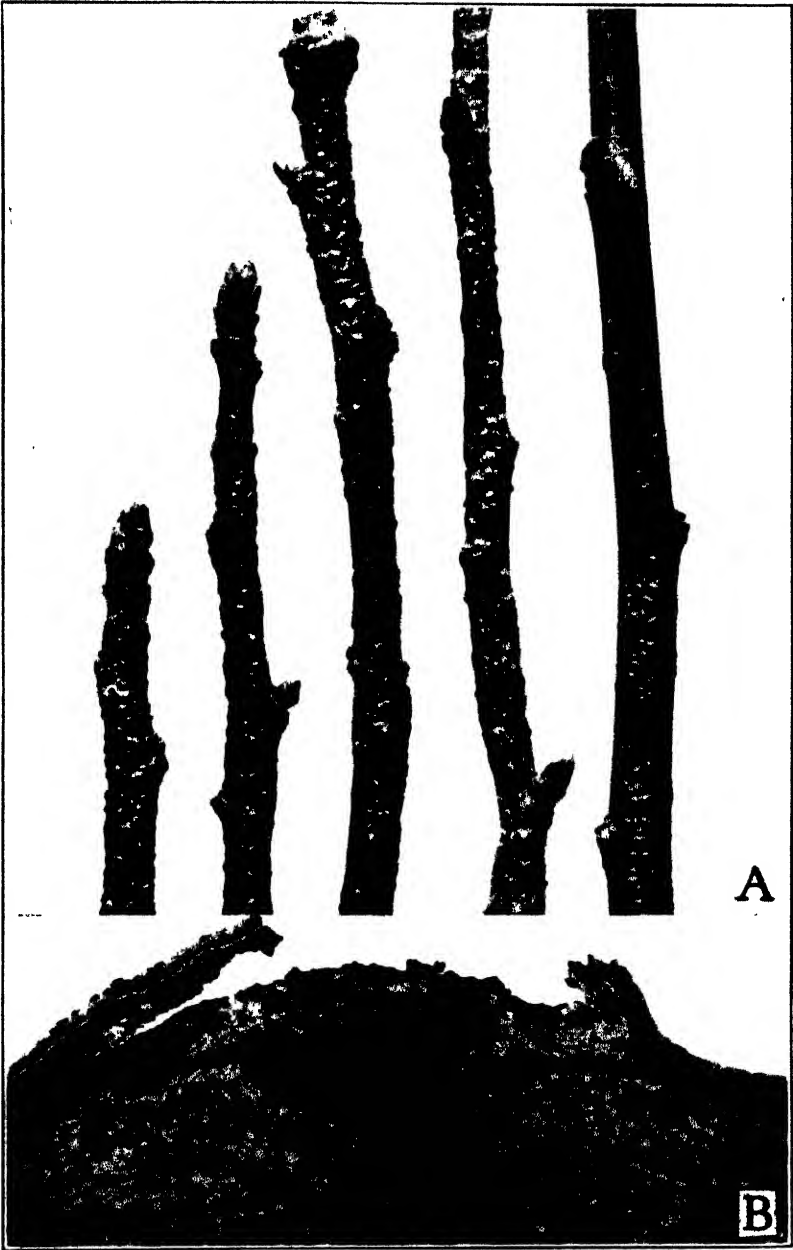
C.—Transverse section through pustular bark of canker on branch of Jonathan apple tree appearing at left in Plate XIX, showing the inclusion of old measles pustules in the outer bark and their demarcation from the surrounding cortex by cork layers. $\times 83$.

PLATE XXI

A severely measles Esopus (Spitzenburg) tree set in 1913. The bark of the trunk and basal portions of the scaffold limbs was densely and conspicuously pustular, but the outer measles bark of the trunk and one of the scaffolds has begun to exfoliate in deep scales.



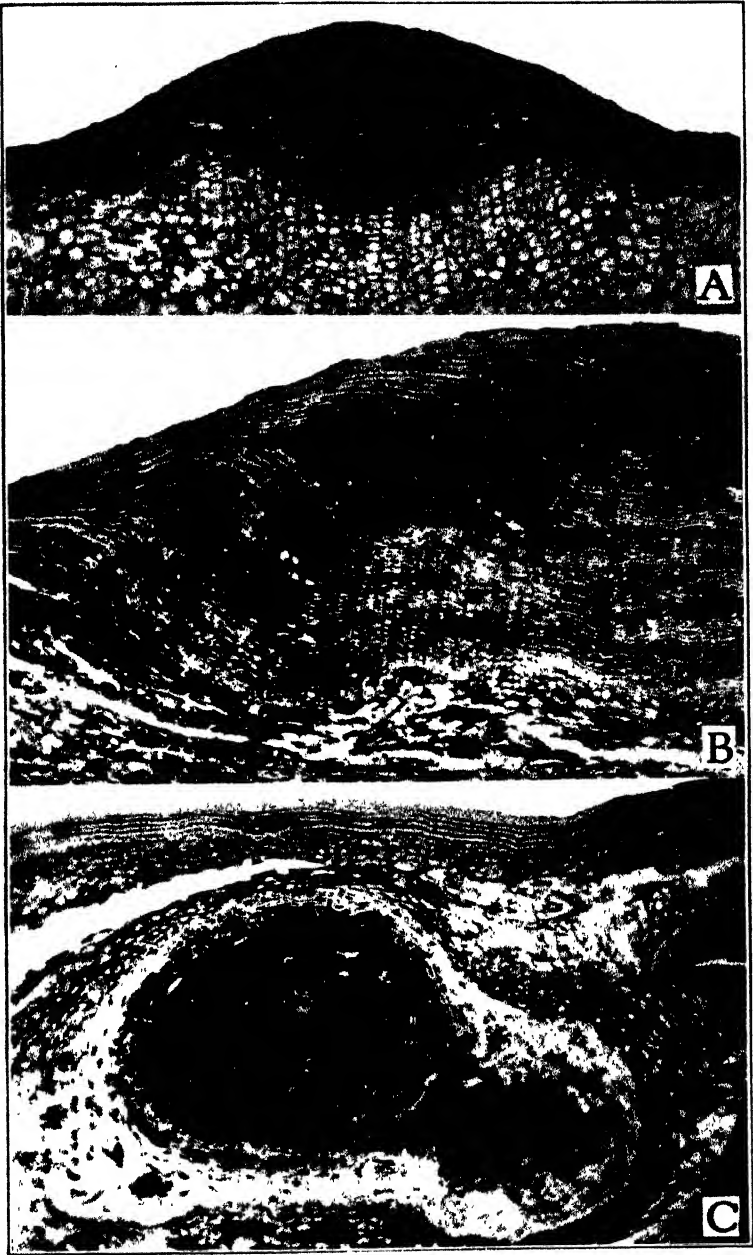
APPLE MEASLES



APPLE MEASLES



APPLE MEASLES



APPLE MEASLES



APPLE MEASLES

WHITE ROT OF ALLIUM IN EUROPE AND AMERICA

J. C. WALKER

WITH PLATE XXII

INTRODUCTION

The white rot (*Sclerotium cepivorum* Berk.) of onion and certain of its allies has been known in Europe since it was first described by Berkeley (1) in 1841. Its serious destructiveness to garlic in northern Italy was related by Voglino (8) in 1902, while its common occurrence in the British Isles was noted by Cotton and Owen (3) in 1920. A recent account by Caballero (2) describes it as of consequence upon the garlic crop in north-eastern Spain. The first authentic report of this disease in America was from Oregon in 1918 and a second report came from Virginia in 1923. The fact that it has become established on our continent and that other infested areas will undoubtedly be located in the future makes it of special present interest to American phytopathologists.

DESCRIPTION AND HOST RANGE

White rot is known to affect onion (*Allium cepa*), Welsh onion (*Allium fistulosum*), leek (*Allium porrum*), garlic (*Allium sativum*), and shallot (*Allium ascalonicum*). It may attack the plant at any time during the growing period, provided external conditions are favorable; moreover, it is not uncommon for it to continue as a bulb rot following harvest. The first sign of the disease upon the growing plant appears as yellowing and dying back of the tissue, beginning at the tips of the leaves and progressing downward. The rate of this advance varies with the rapidity of the fungus attack, which in turn depends upon environment. A gradual decline of the plant may thus continue for some days or weeks, or in the case of young plants it may constitute a rapid wilt and collapse of aerial parts.

Coincident with the early symptoms of the disease above ground, further evidence is noted if the subterranean parts of the plant are examined. The fungus attacks both roots and bases of scales and is itself usually conspicuous by an abundance of superficial, white, fluffy mycelium. The roots are gradually destroyed and the fungus causes a semi-watery decay of the scales not unlike that caused by *Sclerotinia libertiana* on other vegetables. Rather early in the development, minute, black sclerotia are formed (See plate XXII,A). These are uniformly spherical, hard, and not over a half millimeter in diameter. They form either on the surface of or are imbedded within the decaying tissue. In any case they become readily detached as the decay progresses. In extreme cases the entire subterranean portion of

the plant may be almost completely destroyed, and the plant then offers no resistance to being pulled.

In case of late infection, the fungus also almost invariably invades at the base of the bulb and nearly full-grown bulbs may thus show early stages of the disease (See plate XXII, B). If such bulbs go into storage or transit, the decay continues.

The manner of attack and symptoms as described apply in general to all species affected; namely, to onion, garlic, leek, and shallot. No exhaustive study of the comparative resistance of species and strains has been made. Cotton and Owen (3) cite shallot and leek as more resistant than onion.

COMPARISON WITH CERTAIN OTHER DISEASES OF ONION

White rot has perhaps been most commonly confused with the *Botrytis* rots which affect onion bulbs following harvest. While the type of decay is somewhat similar, there are several easily distinguishable points of difference. The sclerotia of white rot, which are so abundant and constant except in the very early stages, are less than one millimeter in diameter and thus much smaller than those of any of the three forms of *Botrytis* which occur on onion. The latter most commonly invade through the neck of the bulb, while white rot almost invariably enters at the base. White rot usually makes its greatest advance before harvest, while the *Botrytis* neck rots rarely occur until after harvest.

A decay of garlic bulbs from Italy was noted by Mr. E. D. Eddy in New York City in 1919. From diseased specimens he isolated a species of yellow-spored *Aspergillus*. The latter has been referred to Dr. Charles Thom, U. S. Bureau of Chemistry, who is at present studying the group. Since he has not as yet published a description, it will be temporarily referred to by his number, *Aspergillus* sp. 4660. Inoculations by the writer showed this form to be an aggressive parasite of mature bulbs of both onion and garlic. It might be confused with white rot, inasmuch as the fungus forms sclerotia abundantly in pure culture and in decaying bulb tissue. They are to be distinguished from those of *Sclerotium cepivorum*, however, by the fact that they are somewhat lighter in color and average about double the size. Accompanying the production of sclerotia by *Aspergillus* sp. 4660, there is also commonly formed on the decaying tissue a yellow mold which consists of the conidia and conidiophores of the fungus.

Fusarium bulb-rot, which most commonly starts at the base of the bulb after mid-season, might be confused with the early stages of white rot, especially in its aerial symptoms. The greater abundance of superficial white mycelium on decayed tissue and the early appearance of sclerotia

are again the chief distinguishing characters of white rot. There is probably no likelihood of confusion by pathologists between white rot and other common diseases of the onion bulb. The aerial symptoms might at times be mistaken for those of mildew, but this should not prove troublesome because of the early appearance of diagnostic characters on the subterranean parts of the host plant.

THE CAUSAL ORGANISM

The organism was described originally by Berkeley (1) as a sterile fungus and named *Sclerotium cepivorum*. Voglino (8) studied the organism in detail and describes the production of sporodochia of hyaline conidiophores 40 to 50 μ in length, upon which are borne spherical, hyaline, catenulate conidia 3 to 4.5 μ in diameter. On the basis of his description he renamed the fungus *Sphacelia allii*. Later workers have not confirmed the description of the conidial form by Voglino, and though Cotton and Owen (3) noted the production of microspores, they never succeeded in bringing about their germination. The fungus exhibits several points of resemblance to *Sclerotinia* and further morphological study may lead to the discovery of a perfect stage or functional conidia.

It would appear, however, that in nature the fungus overwinters in the form of sclerotia. The sclerotia germinate readily under proper conditions of moisture and temperature, and the hyaline, branched mycelium grows rapidly as a saprophyte. It probably may live for long periods on dead refuse in the absence of the host. It is known to remain viable for several years in the soil without the presence of host plants.

Strains of the fungus were collected by the writer in 1922 from the British Isles, Holland, France, Spain, and Teneriffe. These all appear to resemble one another in general character but they are still being studied comparatively as to morphological and physiological details. Part of this study is being taken up by Prof. Whetzel, and since the results will be published at a later date, further discussion of the causal organism will be deferred.

DISTRIBUTION AND IMPORTANCE IN EUROPE

Previous reports of occurrence in England (1, 3), Italy (8), and Spain (2) have been cited. These were supplemented by a personal survey by the writer in a number of onion and garlic growing regions of Europe in 1922. In England the disease has been carefully surveyed by Cotton and Owen (3). They report its wide occurrence throughout the British Isles and regard it as of considerable economic significance. The disease appears in May or earlier on the spring-sown onion crop and is most destructive during June and early July. Few new infections occur during August and

most of the early infected plants have died by this time. In autumn onions are commonly sown in England for the spring bunching trade. Certain of these plantings were found by the writer to be severely affected with white rot in September. Leek also suffers from the disease during the cooler months. Growers in England have in large measure learned to avoid infested areas and the long persistence of the fungus in the soil is generally recognized.

In Holland the disease exists in the onion-growing sections in the islands of Zeeland, but apparently not to so destructive a degree as in England. It is probable that judicious rotation in this intensive truck growing region has served to hold the disease in check. The disease is known in France (4) and no doubt at times is quite destructive. It was collected by the writer on both onion and leek in Brittany in June, but apparently, was not a serious factor in the onion-growing section of that province. Sorauer (7) describes from Germany a disease caused by *Sclerotium cepivorum*, but from his discussion it seems more likely that he was referring to one of the Botrytis rots of the onion bulb.

In northern Italy, the disease is still one of consequence to the garlic crop, which is started in late fall or early winter. It is described by Voglino (8) as especially destructive in cool, wet, spring weather, and my observation at Turin in the latter part of May showed the disease in advanced stages. No report from central or southern Italy has been noted by the writer. In Spain garlic is started during the winter months and matures in mid-summer. It is grown commercially usually in the foothill regions, rather than at sea level. Intensive onion production is carried on in the much warmer coastal plains in the vicinity of Valencia and La Coruña. The onion seed is sown in beds from August to January and the seedlings are transplanted from February to April. The early crop matures in July, and the later and larger of the two crops, in August. White rot has been known as a destructive disease of garlic in the province of Cataluña, especially in the intensive section surrounding the small town of Bañolas, for twenty or more years. Personal observation in this section showed nearly every field to be more or less affected and in many fields in roughly circular areas one to several rods in diameter were found in which most or all the plants had been killed by May 15. The organism seems to be most destructive here, as in other cases noted, in the moderately cool part of the growing season. Search in both of the onion sections—Valencia and La Coruña—failed to reveal any evidence of white rot. It is either entirely absent or of minor importance in these sections. It is an interesting question as to whether these are cases of chance escape or whether the soil or environment are such as to prevent the establishment of the fungus as a destructive parasite.

The Canary Islands were visited in late June, just as the onion crop was being harvested. An occasional bulb was found decayed by *Sclerotium cepivorum*, indicating that early in the season it may have been even more destructive.

White rot may thus be considered a disease of widespread occurrence throughout western Europe. Under certain conditions it becomes a very destructive malady and one that may be looked upon with considerable concern by American onion growers. One is led to suspect that its introduction into any one of our intensive onion-growing sections, where continuous cropping with onions is so often the rule, would lead to its establishment as a destructive disease, provided envioning conditions were favorable. From general observations in Europe it would appear to thrive best at moderately cool temperatures and with moderate soil moisture.

OCCURRENCE IN AMERICA

The references to *Sclerotium cepivorum* on onions in Ohio which were made by Selby (6) and by Humbert (5) are undoubtedly erroneous, since it is quite obvious from their description that they were dealing with one or more of the species of *Botrytis* which cause the neck-rot disease. The first authentic collection of the disease in America of which we have record was made in June, 1918, near La Grange, Oregon, by County Agent P. H. Spillman. The fungus was found on both garlic and multiplier onion. Specimens were sent first to Prof. H. P. Barss, at Corvallis, Oregon, who in turn forwarded them to Prof. H. H. Whetzel, at Cornell University, Ithaca, N. Y. The latter isolated the organism and diagnosed it as *Sclerotium cepivorum*, but made no published report. Within the past year this collection and culture have been compared by the writer with material obtained at various points in Europe and the identity of the American collection has been confirmed. No recurrence of the disease in Oregon had been reported up to 1923. In March, 1923, diseased specimens of multiplier onion were sent to the writer from a farm near Norfolk, Va., by Prof. Herbert Spencer. These were also found to be attacked by *Sclerotium cepivorum*. In the late autumn of 1923, Mr. R. J. Davis, Pathologist at the Norfolk Station, reported that on the same farm four acres of multiplier onions were severely damaged by the disease.

Our soil temperature and soil moisture studies (9), which will be reported in detail in another paper, indicate that the disease is most destructive at an average temperature of 15° to 18° C. and at medium soil moisture. The conditions under which our winter crops of shallot and onion are grown in the southern states would appear to be very favorable for the disease and simulate in a general way the conditions under which it is most destructive in Europe. The recurrence of the disease at Norfolk

in even more destructive form the second season supports this assumption. The existence of a favorable environment in the northern onion sections is not so certain. Except in the early part of the growing season the average soil temperature is probably somewhat higher than the optimum for the disease. We, of course, have yet to learn the effects of our northern winters upon the parasite.

MODES OF FURTHER INTRODUCTION AND DISSEMINATION

Enough has been said regarding the disease to imply that the principal means of wide dissemination of the fungus is the transportation of infected bulbs or plants, or by containers of the same. It is not likely that affected bulbs ever produce seed and there is still less probability that seed, except under unusual circumstances, becomes contaminated and thus constitutes a channel of distribution. We may therefore look to the trade practices which involve the transport of bulbs and seedlings as the chief means of introduction into new localities..

There are imported each year into the United States a million bushels or more of onion bulbs for food purposes from various countries in Europe and Africa. While the largest portion of this quantity comes from the Valencian district of Spain, which appears to be free from white rot, imports are commonly made during years of crop shortage from Holland, Belgium, France, Roumania, Italy, and Egypt. It is likely that some of such shipments come from infested areas and may carry more or less of the white-rot fungus. However, the probability of introduction and establishment of the parasite in our soils by this means is comparatively remote. Should bulbs of *Allium* be introduced for propagative purposes, the probability would be much greater, but such practice is subject to the provisions of the Plant Quarantine Act.

The quarantine against garlic bulbs for propagative purposes is not so easily applied, however. Several million pounds of garlic are annually imported to the United States from southern Europe, and undoubtedly some of them come from areas infested by *Sclerotium cepivorum*. Though they are ostensibly all imported for food purposes, there is nothing to prevent some of the bulbs being used for propagative purposes. This channel is, therefore, undoubtedly the one by which introduction of the disease into our soils from abroad is most likely.

Once established in a few localities in America the danger of rapid spread, as a result of practices of extensive distribution of seedlings and bottom sets of onion, is imminent. If conditions prove favorable for its development in one or more of our intensive bottom-set-growing sections, it is obvious that widespread distribution will soon follow. The rapidly increasing traffic in southern-grown onion seedlings for both southern and northern market gardens is an equally important channel.

SUMMARY

1. White rot is a disease of onion and related plants which is very destructive in certain parts of Europe. Its recent appearance in America is therefore of special interest to phytopathologists.

2. The disease is known to affect common onion, Welsh onion, leek, shallot, and garlic. The symptoms are described and compared with those diseases with which it is liable to be confused.

3. The causal organism (*Sclerotium cepivorum*) overwinters and persists indefinitely in the soil under European conditions. The fungus is sterile except for the production of microspores, germination of which has never been observed.

4. White rot is more or less common throughout western Europe; it is often seriously destructive to onion and leek in the British Isles and to garlic in Spain and Italy.

5. Two authentic reports of its occurrence in America have been recorded. It was noted on multiplier onion and on garlic in northeastern Oregon in 1918, but no recurrence has been observed in that locality. It was found on multiplier onion near Norfolk, Virginia, in March, 1923, and recurred in much larger proportion in the autumn of the same year.

6. Observation in Europe and laboratory experiments by the writer indicate the disease to be most destructive in a moderately cool soil (15° to 18° C.), having a medium moisture content. The conditions which prevail for the winter crop of onion, garlic, and shallot in our southern states seem to be most favorable for the disease. It remains to be determined whether the conditions under which our northern onion crop is grown offer a favorable environment.

7. The chief mode of widespread dissemination is on diseased bulbs or seedlings. Further introduction of the parasite into American soils is most likely by way of garlic bulbs imported for food purposes but occasionally diverted to use in propagation. With the large traffic in bottom-sets and seedlings of onion in this country there is great danger of widespread and rapid dissemination from original centers of infection.

OFFICE OF COTTON, TRUCK AND FORAGE CROP DISEASE INVESTIGATIONS,
BUREAU OF PLANT INDUSTRY,
WASHINGTON, D. C.

LITERATURE CITED

1. BERKELEY, M. J. Notices of British fungi. Ann. and Mag. Nat. Hist. 6: 355-365. 1841.
2. CABALLERO, A. El Bioxat, o enfermedad de los ajos, en Bañolas. Bol. de la R. Soc. Esp. de Hist. Nat. 22: 210-212. 1922.
3. COTTON, A. D., and OWEN, M. N. The white-rot disease of onion bulbs. Jour. Min. Agr. of Great Britain 26: 1093-1099. 3 fig. 1920.

4. DELACROIX, GEORGES and MAUBLANC, ANDRE. *Maladies des plantes cultivees*. 447 p., 87 pl. 2nd Ed. Paris. 1916.
5. HUMBERT, J. G. The neck-rot of white onions. *Mo. Bul. Ohio Agric. Exp. Sta.* 1: 176-180. 1 fig. 1916.
6. SELBY, A. D. A brief handbook of the diseases of cultivated plants in Ohio. *Ohio Agric. Exp. Sta. Bul.* 214: 307-456. 106 fig. 1910. Literature cited, p. i-vii.
7. SORAUER, PAUL. *Handbuch der Pflanzenkrankheiten*. II. Die pflanzlichen parasiten. Bd. 2: 550 p. 3 Auf. Berlin. 1908.
8. VOGLINO, PIETRO. Sul parassitismo e lo sviluppo dello *Sclerotium cepivorum* Berk. nell' *Allium sativum* L. *Stazioni Sperimentali Agrarie Italiane* 36: 89-106. Pl. 1-2. 1903.
9. WALKER, J. C. Occurrence of white rot of *Allium* (*Sclerotium cepivorum* Berk.) in Europe and America. *Phytopath.* 14: 26. 1924.

DESCRIPTION OF PLATE XXII

PLATE XXII, A. White Portugal onions produced from sets which were planted in soil thoroughly infested with *Sclerotium cepivorum*. Note that the fungus has completely destroyed the roots and is invading the scales. The disease has passed the early stage wherein the fluffy, white superficial mycelium of the fungus is so pronounced, but abundant spherical, hard, black sclerotia have formed characteristically on the decayed tissue. See further description of the disease in the text. (Enlarged $\times 2$.)

B. Small white "pickle" onions affected with *Sclerotium cepivorum*. Specimens collected in market at Paris, France, in August, 1922. In this instance the plants were evidently attacked late in the growing season since the bulbs seemingly formed normally and the infection is confined to the outer scales. The disease is here assuming the rôle of a storage decay.



SCLEROTIUM CEPIVORUM

SCLEROTINIA INTERMEDIA N. SP. A CAUSE OF DECAY OF SALSIFY AND CARROTS

G. B. RAMSEY¹

WITH PLATE XXIII AND SIX FIGURES IN THE TEXT

For the past four years the writer has been making a study of the transit and market diseases of vegetables on the Chicago market, with special reference to the decay caused by *Sclerotinia* species. During this time, a large number of cultures have been collected and studied, the results of which will be given in a subsequent paper. At the present time, attention is to be called to one strain which has been under observation since April 10, 1920, and which has characteristics that distinguish it from all other *Sclerotinia* species obtainable.

The original culture of this fungus was isolated from the roots of salsify (*Tragopogon porrifolius* L.). Decaying roots were found with a fine, rather appressed cottony mycelium covering slightly sunken, watery lesions which showed a pinkish discoloration around the border. Macroscopic observations indicated that this fungus belonged to the genus *Sclerotinia*, but it was not until the sclerotia began to form that obvious differences appeared which seemed to characterize it as distinct from other species isolated.

This fungus was again isolated from the roots of carrot in February, 1921, but since that date has not been found. Up to the present time over two thousand isolations of fungi from market produce have been made in the Market Pathology laboratory, and almost three hundred of these have been of the genus *Sclerotinia*. Judging from these data, it seems fair to conclude that the *Sclerotinia* sp. mentioned above is, so far, of minor importance or that it comes from more or less localized districts which do not ship much produce to the Chicago market.

Since 1920 this fungus has been carried in culture and compared with the cultural characteristics of all the *Sclerotinia* strains that could be found upon the market and all strains that could be obtained from fellow workers located at the various experiment stations and agricultural Colleges.

Sclerotinia cultures have been obtained from practically all important

¹ Contribution from the Research Laboratory on Market Diseases of Vegetables and Fruits; United States Department of Agriculture, Bureau of Plant Industry, and the Botany Department, University of Chicago cooperating.

The writer wishes to express his thanks to Prof. H. H. Whetzel, of Cornell University, and Prof. Frank Dickson, of the University of British Columbia, for comparing this strain with the cultures of the genus *Sclerotinia* in their respective laboratories, and for helpful criticism in the preparation of this paper.

truck and market garden districts of the United States and the host range includes all of the economic vegetables that are subject to decay by *Sclerotinia* spp. No cultures have ever been found identical with the strain under consideration, and no description in the literature is applicable to this fungus. In view of the facts above mentioned, it seemed advisable to describe this fungus as a new species. Accordingly, the writer offers the following name and description.

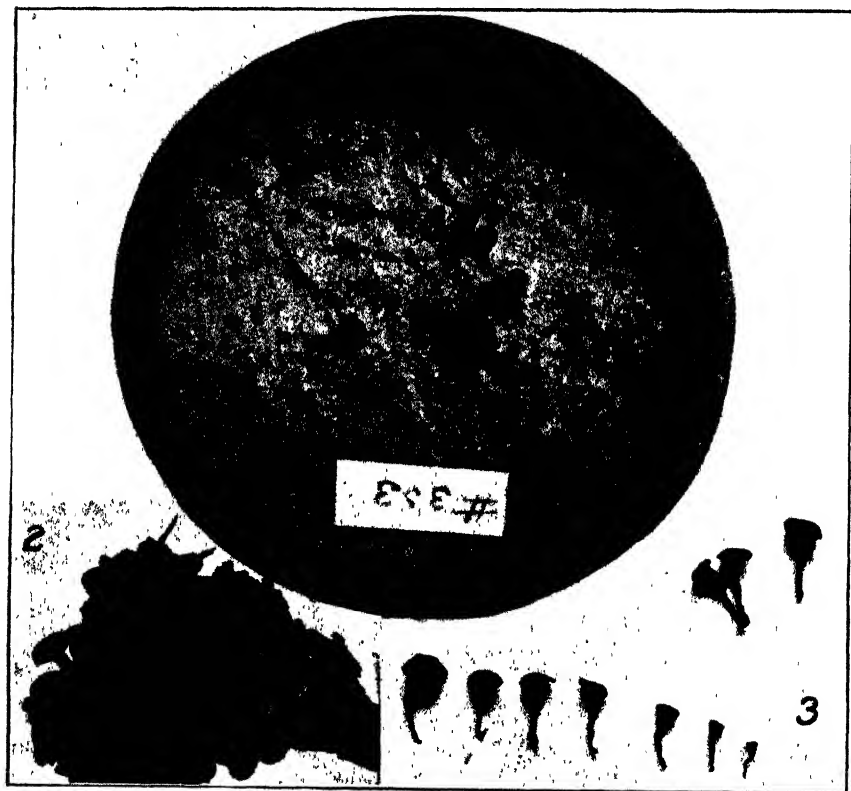
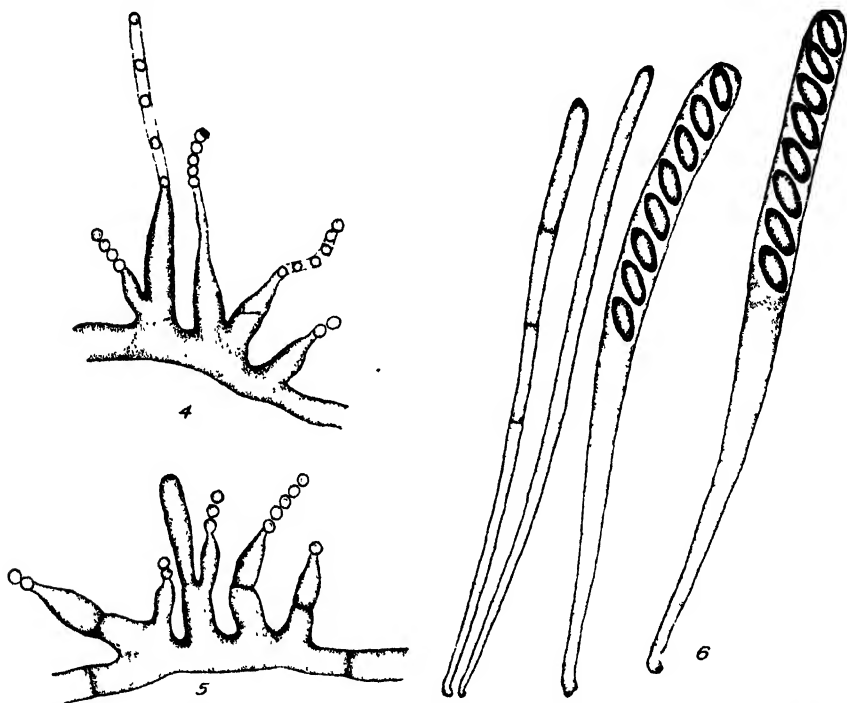


Fig. 1. Unexpanded apothecia of *S. intermedia* as they appear when first coming through the sand in pot cultures. Fig. 2. Cluster of apothecia arising from sclerotia grown on corn meal moistened with prune juice in flask culture. Fig. 3. Stages in the development and expansion of the apothecia.

Sclerotinia intermedia n.sp. Apothecia funnel-shaped to discoid, one to several from a single sclerotium ranging from 2.5 to 6 mm. diameter, average 3.5 mm.; 7 to 12 mm. high, average 9 mm. Stipe cylindrical, 1 to

1.25 mm. diameter, attenuated downward. Disc tawny-olive² at first, changing to snuff brown at maturity, cinnamon buff after ejection of spores. Asci 8 spored, cylindrical to cylindro-clavate, 7.2 to 7.7 by 121.6 to 131.4 microns, average 7.5x127.0 microns. Ascospores elliptical to ovoid, unicellular, hyaline, 3.8-5.7x10.4-15.2 microns, average 4.9x12.7. Paraphyses filiform, simple. Microconidia globose, hyaline 3.8 microns diameter,



Figs. 4 and 5. Manner of microconidial formation on vegetative hyphae. Fig. 6. Asci and paraphyses of *S. intermedia*.

formed acrogenously on short, flask-shaped sterigmata; sometimes produced endogenously in liquid media. Sclerotia black, irregular, 1 to 3 mm. diameter, averaging 2.2 mm. often joining together in elongated chains. Mycelium fine, cottony, white to pale olive buff or cartridge buff colored, forming Roman green appressoria at contact with foreign bodies.

On roots of salsify (*Tragopogon porrifolius* L.) and carrot (*Daucus Carota* L.) on the Chicago market.

Sclerotinia intermedia differs from the almost ubiquitous *S. libertiana* in that the vegetative growth is less luxuriant and cottony, and that the

² Ridgway, Robert. Color standards and color nomenclature, Washington, D. C., 1912

mycelium is not always pure white, but often pale olive buff to cartridge buff in color. On standard nutrient media such as potato-dextrose, oatmeal and bean agar, the mycelium of *S. intermedia* is more scant, finer and appressed, and has more appressoria than *S. libertiana*. The sclerotia of the former are also much smaller and more numerous on the above mentioned media.

S. intermedia produces slightly more mycelium than *S. minor*, and the radiating hyphae form a more appressed compact layer. The sclerotia of *S. intermedia* are larger in diameter and are more fleshy in texture. They often have a tendency to form elongated chains made up of two to several sclerotia joined together end to end. In *S. minor* the sclerotia have a tendency to join together in crust-like formation.

In addition to the above mentioned growth characteristics and the differences in spore and asci measurements, the temperature reactions of *S. intermedia* are quite distinct. This difference is especially noticeable at temperatures just below and a few degrees above 0° C. At—5 to 3° C. it grows about twice as fast on potato-dextrose agar, as either *S. minor* or *S. libertiana*. At temperatures around 7° C. each of the three named species grow at approximately the same rate, while at 20° C. *S. intermedia* develops at about one half the rate of the other species.

S. intermedia produces a watery, soft rot of all the ordinary truck crop plants that are commonly attacked by Sclerotinia. Inoculation experiments have shown this fungus pathogenic to the following hosts:

Asparagus shoots	Cucumber fruits	Pea pods
Bean pods	Lemon fruit	Sweet potato roots
Beet roots	Lettuce heads	Turnip roots
Carrot roots	Parsnip roots	Tomato fruit
Celery stalks		

Of the numerous inoculation tests conducted only the potato tuber has shown complete resistance to *S. intermedia*. The decay produced in all other host plants is quite comparable to that caused by the other species of Sclerotinia, and in most cases is indistinguishable, until a pale olive-buff color of the mycelium becomes noticeable or until sclerotial formation begins.

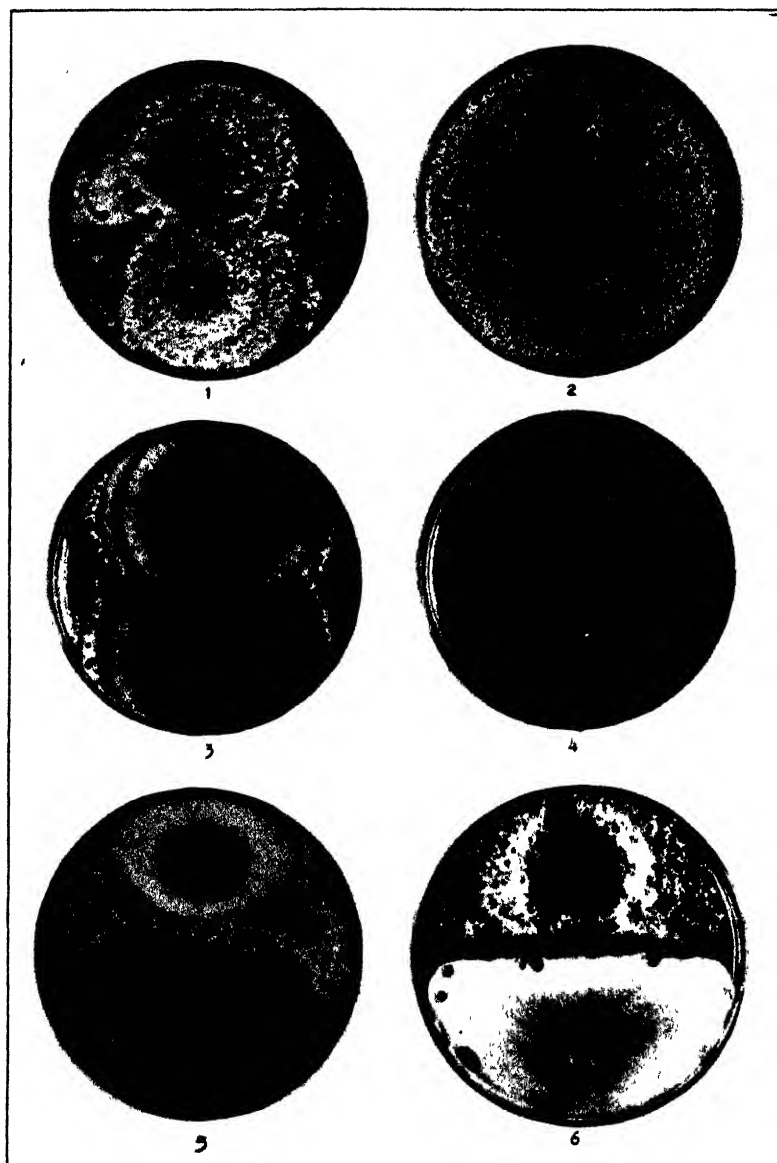
SUMMARY

1. A strain of Sclerotinia found on the Chicago market causing decay of the roots of salsify and carrots has shown morphological and physiological differences which distinguish it from all other species of the genus Sclerotinia.

2. The sclerotia formed upon most culture media are intermediate in size between those produced by *S. libertiana* and *S. minor* and an intermediate amount of mycelium is produced. Hence the descriptive name *S. intermedia* is proposed for this species.

DESCRIPTION OF PLATE XXIII

Fig. 1. **S. intermedia** on potato-dextrose agar. Fig. 2. *S. minor* on potato-dextrose agar. Fig. 3. **S. intermedia** on potato agar without dextrose. Fig. 4. *S. minor* on potato agar without dextrose. Fig. 5. Planting of **S. intermedia** (above) and *S. minor* (below) on the same plate of potato-dextrose agar and grown at room temperature. Note the difference in rate of growth and in the character and amount of mycelium and sclerotia formed by the two species. Fig. 6. **S. intermedia** (above) and *S. libertiana* (below) growing together on potato-dextrose agar at 5-7° C. showing equal rate of growth at this temperature.



SCLEROTINIA CULTURES

SPHAEROPSIS MALORUM AND MYXOSPORIUM CORTICOLA ON APPLE AND PEAR IN OREGON.

S. M. ZELLER

Stillinger¹ has already reported from Oregon on apple rot caused by a hyaline-spored fungus of the *Macrophoma* type which he believes does not produce apple canker. He was also unable to find either the brown spores of the *Eu-sphaeropsis* type or the *Diplodia* type, which are characteristic of *Sphaeropsis malorum* Berk., as it is found in the eastern part of the United States. For these reasons the writer and other Oregon pathologists have wondered whether perhaps the Oregon fungus might not differ materially from the true black rot organism as described by Hessler and others. The writer thought it worth while, therefore, to examine collections of apple and pear cankers which for several years have been accessioned with notes in the Department of Botany and Plant Pathology.

The writer feels that a few facts concerning these collections, and cultures from certain of them, are well worth while recording here to help clear up the situation with reference to *Sphaeropsis malorum* Berk. in Oregon, and incidentally a note concerning the limited occurrence of *Myxosporium corticola* Edg. in the state.

SPIAEROPSIS

Herewith in table 1 is presented the essential data of Oregon collections which may be referred to *Sphaeropsis malorum* Berk. without question. As far as already known, the fungus has been observed from the Hood River, Willamette and Unipqua Valleys in Oregon.

The fungus has usually been found as a bark canker, often on small branches, killing the bark and discoloring the wood to some depth, as in the case of other die-back organisms, often following slight sunscald or winter injury, and sometimes associated with Nectria galligena on loose dead bark over canker spots. The canker doubtless occurs endemic in the fruit growing districts of the Willamette and Hood River valleys, but is usually found in orchards which have been abandoned or in those which do not receive the usually-prescribed sequence of sprays suggested for the control of other fungous diseases. The black rot canker assumes its worst form when its infection is subsequent to other fungi, winter injury, sunscald, or die-back from various causes. Of itself Sphaeropsis malorum

¹ Stillinger, C. R. Apple black rot (*Sphaeropsis malorum* Berk.) in Oregon. Phytopathology 10: 453-458. 1920. Literature cited, p. 458.

Date of Collection	Collector	Collection to be found in	Locality	Host	Form	Measurement of pycnospores in μ	Form of Spores to be found in collection
Feb. 21, 1911	F. D. Bailey	O.A.C. Plant Path. Dept. Acc. A80, Zeller Herb. 2504	Corvallis	Apple	Bark Canker	27-38 \times 10-13	Hyaline and brown, 1-celled; brown, diploid
Oct. 23, 1911	H. L. Rees	Acc. B45	Hood River	Apple	Bark Canker	30-35 \times 11-13	Hyaline and brown, 1-celled; brown, diploid
Feb. 27, 1912	H. L. Rees	Acc. B149	Corvallis	Apple	Bark Canker	28-34 \times 12-16	Hyaline and brown, 1-celled; brown, diploid
April 3, 1912	H. L. Rees	Acc. B201b	Forest Grove	Apple	Bark Canker	24-32 \times 10-12	Hyaline and brown, 1-celled; brown, diploid
April, 1912	H. L. Rees	Acc. B205b	Salem	Apple	Bark Canker	26-30 \times 11-14	Hyaline, 1-celled; brown, diploid
Feb. 15, 1913	H. L. Rees	Acc. B113x	Corvallis	Apple	Bark Canker	22-32 \times 10-14	Hyaline, 1-celled; brown, diploid
July 18, 1919	S. M. Zeller	A.O.C. Negative 19268	Roseburg	Apple	Bark Canker	25-32 \times 10-12	Hyaline, 1-celled; brown, diploid
Aug. 14, 1919	S. M. Zeller	Zeller Herb. 1603	Salem	Apple	Leaf Spot		
Aug. 15, 1919	S. M. Zeller	Zeller Herb. 1579	Corvallis	Apple	Leaf Spot		
Aug. 28, 1920	S. H. van Trump	O.A.C. Plant Path. Dept. Acc. D661	Salem	Apple	Bark Canker	25-29 \times 10-14	Hyaline, 1-celled; brown, diploid
Nov. 4, 1922	S. M. Zeller	Zeller Herb. 2374	Hood River	Apple	Leaf Spot		Primordial pycnidia
Jan. 4, 1923	F. M. Green	Zeller Culture 127	Hood River	Apple	Fruit Rot		
Feb. 20, 1923	V. W. Mason	Zeller Herb. 2493	Albany	Apple	Bark Canker	25-34 \times 11-15	Hyaline, 1-celled; brown, diploid
March 1, 1923	V. W. Mason	Zeller Herb. 2496	Albany	Apple	Bark Canker	26-35 \times 12-15	Hyaline and brown, 1-celled; brown, diploid
Feb. 27, 1912	H. L. Rees	Acc. B104	Salem	Pear	Bark Canker	21-25 \times 7-10	Hyaline, 1-celled; brown, diploid

seems to cause merely a superficial cortex canker under Oregon climatic conditions.

The pycnidial form of fruiting on the bark evidently occurs more abundantly on apple than on pear and seldom matures further than the *Macrophoma* stage. After spores are discharged, however, and are lodged upon the bark surrounding the pycnidia, they become brownish and usually diploid. No true *Diplodia* has been found by the writer on apple or pear in Oregon. In fact, no other pycnidial forms have been seen on the same areas of dead bark occupied by pycnidia of *Sphaeropsis malorum*. Thus we feel safe in assuming that the colored spores are those from the *Macrophoma* type of pycnidia, since such diploid spores produce the *Macrophoma* with typical spores when cultured.

Black rot is endemic as a leaf-spot in Oregon. It is confined mostly to old or neglected orchards in sod, although an occasional outbreak in individual rochards is serious in some localities under favorable weather conditions. The unusually-few serious cases of leaf-spot in Oregon undoubtedly is due to the dry summer climate, there seldom being a rain after the leaves have opened until they have reached advanced maturation, or until just before leaf fall. Otherwise, with the casual organism as prevalent as it seems to be, there is no known reason why Pacific north-western orchards should not suffer their share of damage from black rot leaf-spot.

The leaf-spot as it occurs here is the typical "frog-eye." Seldom, however, do pycnidia mature on the leaves. Black specks do frequently occur in the leaf-spots. When the epidermis is lifted away, these specks prove to be sclerotia (perhaps primordial pycnidia, mature specimens of which have not yet been observed). When these sclerotia are dissected out with a sterile needle and planted on agar slants they yield a mycelial growth typical of the black rot organism (compared with culture from Hesler). Apples have been inoculated from such cultures, which cause a black rot of the fruit, upon which pycnidia of the *Macrophoma* type described above have been produced.

Black rot of the fruit occurs rather frequently, as Stillinger has suggested. This, I believe, is most prevalent during the fall after early rains and, of course, would be most serious on the late picking varieties, such as Newton Pippin. No specimens of pear fruits decayed by this organism have been recorded.

The same growth in culture and the same type of rot of apple fruit has been obtained with fungous cultures secured from the three sources, i.e., leaf-spot, bark canker, and fruit rot. All of these cultures have given in return the typical pycnidia on inoculated apple fruit, and some on agar and sweet clover stems.

TABLE 2.—Occurrence of bark canker caused by *Myrosporum corticola* Edg. in Oregon.

Date Collected	Collector	Collection to be found in	Locality	Host	Measurement of spores in μ	Form of Conidia to be found in collection
Sept. 20, 1911	H. L. Rees	O.A.C. Plant Path. Dept. Acc. A 66D6	Corvallis	Pear	20-30 \times 8-10	Hyaline, 1-3-septate before germinating
Oct. 11, 1911	H. L. Rees	Acc. A 100	Corvallis	Pear	24-25 \times 11-12	Hyaline, 1-celled
Dec. 19, 1911	H. L. Rees	Acc. B 105	Salem	Pear	22-24 \times 10-11	Hyaline, 1-celled
Dec. 22, 1911	H. L. Rees	Acc. B 105a	Salem	Pear	24-30 \times 7.5-10	Hyaline, 1-3-celled, also ochraceous
April 3, 1912	H. L. Rees	Acc. B 201a	Forest Grove	Apple	18-22 \times 10-12	Hyaline, 1-celled
Dec. 6, 1922	S. M. Zeller	Zeller Herb. 2628	Medford	Pear	22-28 \times 7.5-11	Hyaline, 1-3-celled
Feb., 1923	S. M. Zeller	Zeller Herb. 2627	Corvallis	Pear	20-30 \times 8-12	Hyaline, 1-3-celled
March 21, 1924	S. M. Zeller	Zeller Herb. 2648	Spring Brook	Apple	22-28 \times 8-12	Hyaline, 1-celled

To summarize: There is no doubt that black rot of pomaceous fruits is wide-spread in Oregon—perhaps throughout the Pacific Northwest—but its economic importance is limited because of the dry summer climate. Its presence and identity have not previously been definitely reported because the development of the pycnidia spores is not usually matured to the Sphaeropsis or diploid stages.

MYXOSPORIUM

Myxosporium corticola Edg. occurs in Oregon as a superficial bark canker. Its known distribution as indicated in the above table is limited to the Willamette and Rogue River Valleys, and it has been found more often on pear than apple. The infected areas of bark are typical of those described by Edgerton,² and Hesler and Whetzel³ and others. The affected bark is sunken and browned under the epidermis, but not to the inner bark and cambium. The diseased bark dries and shrinks, leaving a marginal crack. On these sunken areas appear the acervuli, which often exude white or creamy, globular masses of spores. The spores are hyaline, measure 18-30x7.5-12 μ and are unicellular, becoming 1-3-septate and often yellowish before germination.

There is apparently no lasting or damaging effect on trees which have bark infections due to this fungus. There is apparently no decay of fruit due to this organism, at least such was not induced by artificial inoculation.

OREGON EXPERIMENT STATION,
CORVALLIS, OREGON.

² Edgerton, C. W. Two little known Myxosporiums. *Ann. Myc.* 6: 48-53. 2 fig. 1908.

³ Hesler, L. R., and H. H. Whetzel. *Manual of fruit diseases*, pp. 130-132. 1917.

MORPHOLOGICAL STUDIES ON THE INJURY TO APPLE CAUSED BY *CERESA BUBALIS*

J. C. GOODWIN AND F. A. FENTON¹
WITH FOUR FIGURES IN THE TEXT

The peculiar lesions caused by oviposition of *Ceresa bubalis*² Fab. in woody plants are familiar to many entomologists. A histological study of these scars was taken up to determine the pathological changes in the plant tissues that take place following the incision of the sharp ovipositor of the female insect. At first cross sections were made from plum, pear and apple wood. Microscopical examination of slide material prepared from these revealed the character of the injury, and this was found to be practically the same for all. Therefore, the following notes are largely based on a study of the malformations produced on apple as a result of egg deposition by this species.

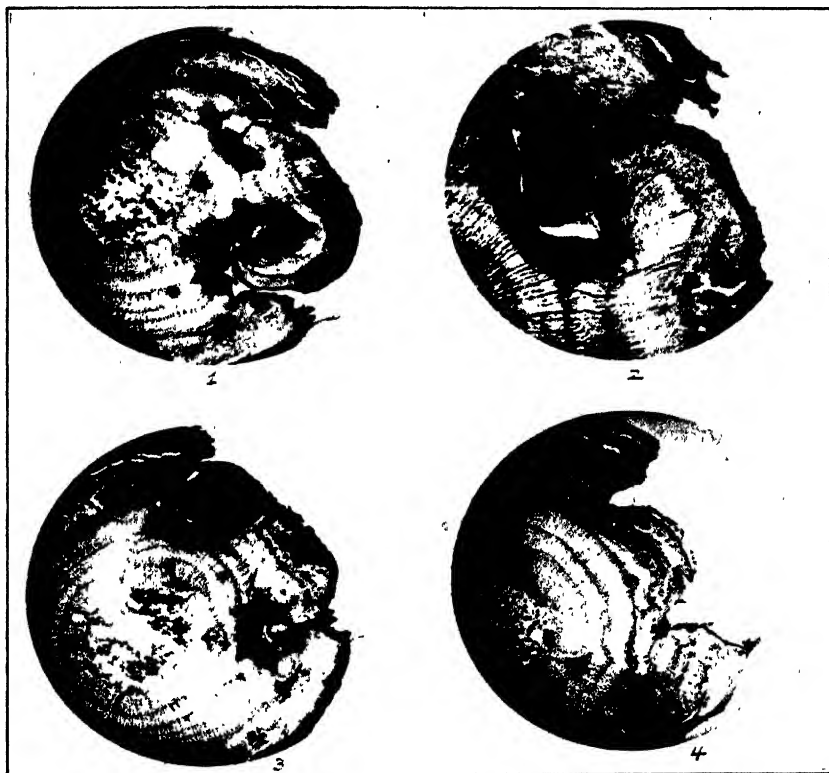
Fresh twigs were secured showing typical injury and cross sections 18 microns thick were cut through the lesions with a sliding microtome. This material was stored in 90 per cent alcohol until needed. The sections were stained in safranin from three to four minutes and were then washed, first in distilled water, and later in 95 per cent alcohol. This process removed practically all of the color from the cells with the exception of the vascular bundles. The wood was then dehydrated and counterstained in a weak hematoxylin solution for three to four minutes. After rinsing to remove an excess of this color, the ground tissue showed a deep blue in contrast to which the red vascular bundles could be easily identified. Permanent balsam mounts were made after dehydration and clearing in clove followed by cedar oil.

Sections through typical one-year old lesions (Fig. 1) showed that the injury was much more severe than apparent from the outside. The sharp ovipositor of the female is inserted through the cambium layer and deep into the woody fibre. These cuts often penetrate almost to the center of small branches. Directly after oviposition there is formed over that part of the wood thus exposed to the air, a corky layer of cells. The two strands of corky bark adjacent to each other on both sides of the incisions do not unite (Fig. 2). Because of this, a wedge-shaped section of the wood becomes separated from the remainder. That part of the cambium layer within the slits is isolated from the rest and the wound fails to heal over. The severed part of this, as well as the rest, continues to grow and the force exerted between these two results in the malformations of the tissue as illustrated. Often the cambium and adjacent tissues grow to about five

¹ Contribution from the Dept. of Zoology, Iowa State College.

² Order *Homoptera*; family *Membracidae*.

times their size at the time of oviposition. As a result of this abnormal growth of the tissue within the wedge and also because of the pressure exerted against this by the cambium around it, this part is gradually pushed outwards. At the same time the scar increases in size. As this process continues from year to year (Figs. 3 and 4) more and more of the wood between the cuts becomes corked over and sloughs off. Finally, at the end of the fourth or fifth year, the scar has increased considerably in



INJURY TO APPLE CAUSED BY CERESA RUBALIS FAB.

Fig. 1. Cross section through typical one-year-old lesion in apple wood caused by oviposition of *Ceresa bubalis* Fab. Fig. 2. Enlarged view of portion of lesion showing the two corky layers of newly formed bark. Fig. 3. Cross sections through two-year-old lesion. Fig. 4. Cross sections through three-year-old lesion.

width but there has been a corresponding decrease in depth. Altogether, mechanical injury is very severe and there are evidences that decay often sets in due to these wounds. While these may eventually heal over, the organisms have already entered the heart wood and ultimately this secondary injury may kill the entire limb.

THE SELF PRUNING OF WESTERN YELLOW PINE

W. H. LONG

In our native forests of western yellow pine the individual trees, as they grow older, gradually lose their lower branches. This is also true of all forests in general. This dying of the lower branches without any apparent specific cause has been termed "self pruning" by foresters and scientists. The cause of this so-called self-pruning has usually been attributed to shading. As the tree grows the upper branches spread out in all directions toward the light, gradually cutting off the bulk of the sunlight from the lower and smaller branches. These lower branches gradually die and finally fall off.

For several years the dying of the lower limbs on trees of western yellow pine has been under observation. At the beginning of the study it was noticed that many dead and dying branches were present on young trees where shading could not have been the cause since the dead branches were in such positions on the tree that they would receive a large amount of sunlight. An examination showed that the branches of hundreds of yellow pine trees had died even when they were not shaded sufficiently to prevent their growth and development.

A careful examination of such trees showed the presence on the dead branches of the fruiting bodies of a fungus known technically as *Cenangium abietis*. The fungus starts on the lower branches near the ground where the moisture is the greatest, it then gradually works up the young tree year after year until a distance of 20 or 30 feet is reached. It rarely goes higher than 30 feet, due, apparently, to the lack of sufficient moisture that high from the ground. The fungus grows in the living bark and usually starts in a small side or terminal twig, and gradually works back to the larger branches which are finally girdled and killed. Branches of all sizes up to two inches in diameter are attacked and killed. The fungus does not seem to be an active virulent parasite since it attacks branches which are weakened by drouth, shade, etc., however, nearly all of our yellow pine areas are more or less subject to drouth at intermittent periods, and every year our open yellow pine stands are subject to climatic conditions which approach semi-drouths. These weakened branches, if low enough on the tree to be within the range of sufficient moisture for the germination of the fungus and its penetration into the tissues of the tree, are usually attacked and finally killed by the fungus. Such branches, especially, would usually recover after the period of drouth and continue to grow if the fungus did not attack them.

The fruiting bodies of *Cenangium abietis* appear as small black pustules, breaking through the bark on branches which have been dead for several months. These pustules ripen and discharge their spores during the rainy season. It is probable that at this time the new infections occur. A branch attacked by this fungus will have pale yellowish leaves, a dead twig here and there, and a generally unhealthy appearance. A close examination of the bark will show many dead resinous areas on the main branch. These areas finally coalesce thereby girdling and killing the entire branch. Of course, in dense stands shading may be a prominent factor in the self-pruning of the trees but it may also be only secondary since such dense stands are very favorable to the development of the pruning fungus, due to the shade prolonging the moisture conditions necessary to the growth of the fungus.

In many sections of New Mexico and Arizona this pruning fungus is very common and seems to be the usual cause of the self-pruning of the young trees. The semi-parasitic nature of this fungus prevents it from attacking, as a rule, vigorous and rapidly growing reproduction. It seems to limit itself to the lower, older and weakened branches. This early pruning of the branches of young timber is beneficial since more clear lumber will be obtained from such trees when they mature. It is a well known fact that knots, especially large ones, produce lumber of an inferior grade and hence lumber which will not sell for as high a price as that which is free from large knots. All of the lumber used for finishing the interior of our houses and homes must be free of knots and is known to the lumberman as select or clear lumber. Such lumber brings, on the retail market, about three times as much as the lower grades with their many knots. The clear lumber is obtained from the outer portions of the logs which usually come from close to the butt of the trees. All of the new wood added to the bole of the tree, after all of its branches are shed, makes clear lumber since the presence of branches is what produces knots. The earlier, in the life of a tree, that its lower branches are shed, the sooner will clear lumber be produced on that portion of the tree, hence any factor or agency which causes the early pruning of the lower branches on trees is beneficial to the lumberman. It is for this reason that *Cenangium abietis*, the pruning fungus of western yellow pine, is to be considered a valuable asset to our lumbering interests.

OFFICE OF INVESTIGATIONS IN FOREST PATHOLOGY,
BUREAU OF PLANT INDUSTRY,
ALBUQUERQUE, NEW MEXICO.

THE MICROLOOP. A RAPID METHOD FOR ISOLATING SINGLE SPORES.

MARIN S. DUNN

WITH ONE FIGURE IN THE TEXT

Recently while working on *Sclerotinia cinerea* under the direction of Dr. Charles H. Arndt, it became necessary to obtain pure cultures which were the result of single spore inoculations. Several methods were tried but all of them were very tedious. Therefore, attempts to develop a simpler and more rapid method were made. The procedure described in this paper is the outcome of these efforts, and it has been found to be quite satisfactory for the following reasons:

1. Single spores and particular single spores, if not too small, may be obtained rapidly by an easily-made "microloop" of glass.
2. The binocular dissecting microscope at times may be used with ease in the isolation of the spore.
3. Inconvenient cooling and heating agents are not required.
4. Mechanical injury to the spore is avoided.
5. The study of physiological strains is greatly facilitated.

The culture medium to be inoculated (in the form of agar slants or Petri dishes) is placed in a convenient position under a glass plate supported above a laboratory table at such a distance from the table-top that the investigator may manipulate a microscope under it without touching the plate with the head. A Bunsen burner is lighted under the plate about one-half hour before the inoculation is started, and the table-top is wiped with some suitable reagent. An inoculation room may be used instead of the glass plate.

The spores of the species of *Sclerotinia* studied are large enough (a little over 10μ) to be seen clearly under the high power of a binocular dissecting microscope. For more accurate study, a compound microscope with a 16 mm. objective is placed by the side of the dissecting microscope under the plate. A tube of distilled water which has been previously sterilized is put into a convenient position. When necessary, instead of the water, the filtered, sterilized culture medium without agar may be used. In the case of *Sclerotinia cinerea*, the writer first studied the spores under the compound microscope, and later selected those desired under the binocular dissecting microscope.

A large drop of the medium is placed upon one end of a properly-sterilized and flamed clean glass slide. Into this drop, spores from the culture are introduced by means of a sterilized platinum loop, and gently

agitated. Two or three other drops of the water are placed side by side on the same slide. A loopful of drop No. 1 containing the spores is introduced into drop No. 2, a loopful of drop No. 2 into drop No. 3, etc., until satisfactory dilution is obtained. By observing the dilution at different times under the 16 mm. objective, it is possible to find a drop containing a few well-separated spores. Any other satisfactory method of dilution may be used.

The slide is then removed to the dissecting microscope, and the upper surface of the selected drop brought into view. Instead of using a capillary tube to suck up the spore desired, the writer uses what he terms a micro-

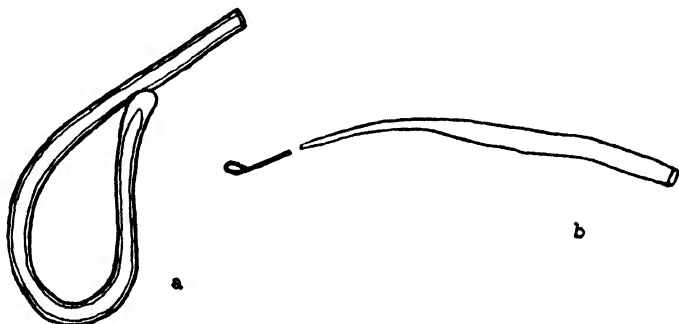


FIG. 1. a, the loop end of one type of microloop, approximately $\times 37$; b, the same microloop showing the general structure and relation of its parts, the loop somewhat magnified.

loop. This is simply a piece of glass rod or glass tubing of small diameter drawn out into a delicate filament at one end, this end being bent to form a minute, flat loop (Fig. 1). If it is made from glass tubing, care must be taken that the central canal of the tube is closed in the loop end. The microloops may be of various sizes and shapes to fit the needs of the investigator. The writer used the one shown in the illustration for his isolation of the spores of *Sclerotinia cinerea*. This loop was approximately $1\frac{1}{10}$ mm. long and $\frac{1}{2}$ mm. wide at its widest part (inside measurement).

It is possible to place the loop immediately over the spore in question so that it appears directly under the center of the loop. By gently lowering the hand until the loop almost touches the liquid around the spore, it is extremely easy to give a slight sudden up and down movement, rapidly touching the loop to the medium, and withdrawing it before any currents may carry other spores to it. As the loop is lifted from the liquid, there is carried with it a small drop of the medium in which, near its center, is held the desired spore. The tube of the microscope is then raised and the drop studied at leisure while held in the loop. When desired, the drop may

be transferred to a sterilized slide and studied under the higher magnification of the other microscope.

However, the writer finds in his work on *Sclerotinia* that it is often sufficient after studying the drop under the dissecting microscope to convey it to an agar slant. The spore is readily removed by simply allowing the drop contained in the loop to touch the surface of the agar. There is no injury due to mechanical handling. The rapidity and accuracy of isolation soon improve as the investigator becomes accustomed to the microloop employed.

It is a great advantage to select spores that are floating on the top of the drop on the glass slide rather than trying to obtain those below the surface. It may be found helpful to bend the glass filament so that the loop is in a plane slightly below the handle. This obviates the possibility that the handle may strike the surface of the medium. After using, the microloop is sterilized in any appropriate manner and reused as often as may be necessary.

If the spore is so small that the use of the dissecting microscope is impossible, it may be found convenient to attach the microloop in place of the capillary tube in a device like the one described by Roberts,¹ and work directly under the 16 mm. objective of the compound microscope, using a microloop of appropriate size.

Although the writer has not reviewed all the literature concerning single spore isolation, he feels since he has had such good results in such a surprisingly easy manner that he is justified in setting forth the method used for the benefit of those who may need an accurate and rapid technique.

BOTANICAL LABORATORIES,

UNIVERSITY OF PENNSYLVANIA.

¹ Roberts, J. W. A method of isolating selected single spores. *Phytopathology* 13: 558-560. 1 fig. 1923.

PHYTOPATHOLOGICAL NOTES

Supplement to Handbook of the Plant Diseases in Japan. Vol. 1, pages 1-398, 1923, by Arata Ideta. This is an attractively gotten up book printed on thin, rough-surfaced paper. Unfortunately from our viewpoint it is printed in Japanese except some citations and names of parasites. Except for some half-tone illustrations, evidently copied from other publications, the illustrations are very good. American bookmakers might well copy the example set by this one and make the use of their books a pleasure instead of a task because of excessive weight, as a result of the use of shiny, heavily calendared paper of low actual grade and length of life. This volume evidently presents the additions to Japanese plant diseases in the groups: Myxomycetes, Bacteria, Oomycetes, Zygomycetes and Ascomycetes. A second volume is to give additions to the remaining groups.

Ideta's Handbook of the Plant Diseases of Japan, issued 1909-11, is fairly well known to American pathologists although printed in Japanese. In a personal letter Ideta states: "The first volume of the Supplement was published in Tokyo last April. But by the great earthquake catastrophe of September first, all copies of the Supplement which were preserved in the bookstore, the Shokabo, Tokyo, were burnt and now only a few copies remain in my hands. The eighth edition of my Handbook was published last May in Tokyo but all copies were burnt also at the same time. . . . The Supplement is to consist of two volumes but I am sorry that it is impossible to publish the second volume in the near future." His address is Arata Ideta, Director of Ogori Agricultural School, Yamaguchi-ken, Japan.

-PERLEY SPAULDING.

A Native Weed Host for Bacterial Blight of Bean. Angular, translucent, watersoaked spots were found upon the young leaves of trailing wild bean (*Strophostyles helvola* (L.) Britton) on September 25, 1923, in experimental plots planted by Dr. E. B. Mains at Purdue University Agricultural Experiment Station, LaFayette, Ind. These leaf lesions proved to be full of bacteria and from them a yellow organism was isolated which in culture closely resembled *Bacterium phaseoli* E. F. S. In the greenhouse in March, nine potted garden bean plants were sprayed with a water suspension of a 24-hour culture of the *Strophostyles* organism and typical, greasy, parchment-like, bacterial blight lesions were obtained on seven of the plants. At the same time two potted *Strophostyles* plants were similarly inoculated with a culture of *Bacterium phaseoli* isolated from garden beans and infection occurred on both plants. The lesions on *Strophostyles* remained smaller than those on garden bean. Reisolations from both host species yielded similar yellow colonies of *Bact. phaseoli*. Therefore *Strophostyles helvola*, a widely distributed native wild plant and in some places a common weed, may function as a host for bean bacterial blight, and should be considered undesirable in the vicinity of cultivated beans.—MAX W. GARDNER.

A Laboratory Convenience.—Many plant pathologists use culture media in connection with certain phases of their work, and are familiar with the inconvenience caused when the cotton plug becomes stuck to the inside of a test tube by a drop of the medium. An occasional drop of medium on the tip of the tubing apparatus is likely to come in contact with the inside of a test tube, near its mouth, unless one is very skillful in the tubing of media. The sketch submitted with this note shows a type of tubing apparatus outlet which has been used in the Plant Pathology Laboratory at the West Virginia Agricultural Experiment Station, for nearly fifteen years. These little double tubes have been found very convenient, and have been reported as quite helpful by men in other departments, where they have been tried. This article is written at the suggestion of some of these users.

The author wishes it clearly understood that he did not design the tube. The first tube of that type used in our laboratory was found in a lot of old, miscellaneous glassware, and was put to use as a tip for our culture media tubing equipment. What it was originally designed for, and what its name may have been, is quite unknown to the writer. No effort has been made to

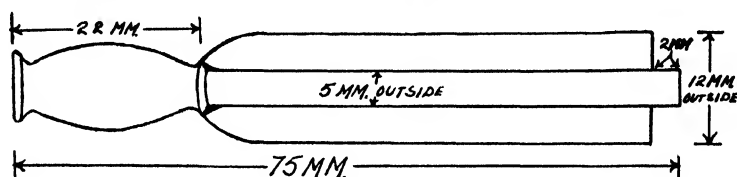


FIG. 1. Outlet for culture medium test tube filler.

learn whether there has been previous publication concerning this bit of glassware.

The tubes which we are now using were made by Eimer and Amend, as a special order. They are not listed in any catalog that has come to our attention.

The upper portion of the tube is single, and with an enlargement to make it hold rubber tubing better. The lower part of the tube is double, and the medium is delivered from the central tube. Even thick culture media, like oat meal agar, pass readily through the small tube, if tubed while hot. The outer tube fits inside any ordinary test tube and helps to keep the medium from contact with the upper part of the test tube. The inner tube should project about two millimeters beyond the outer tube in order to prevent the culture medium from coming in contact with the latter. It has been suggested that making the inner tube about four or five millimeters shorter than the outer tube would also be effective. This has not been tried in our laboratory, but would appear to be less desirable especially with thick media.—N. J. GIDDINGS.

Personals. Dr. H. W. Wollenweber of Berlin, formerly a pathologist in the Bureau of Plant Industry, Washington, D. C., came to this country about the first of June to take part in a conference on *Fusarium* diseases of plants, to be held at Madison, Wis., in June. He stopped in Washington for a few days en route to Madison. Other workers who will participate in this conference are Dr. Otto Reinking, pathologist for the United Fruit Company, Dr. C. D. Sherbakoff of the University of Tennessee, Miss Helen Johann of the Office of Cereal Investigations, Mrs. Alice Bailey of Chicago, and possibly others.

Dr. H. L. van de Sande-Bakhuijzen, a Dutch botanist, stopped in Washington, on his way to California a few days ago and spent a short time in the pathological offices of the Bureau of Plant Industry.

Dr. John R. Johnston, formerly of Washington and now pathologist for the United Fruit Company of Boston, was a recent visitor in Washington.

Dr. R. D. Rands has been transferred from the Office of Crop Acclimatization and Adaptation Investigations to the Office of Sugar Plant Investigations, and will work on sugar cane mosaic.

Dr. G. H. Godfrey has resigned his position in the Bureau of Plant Industry, Washington, D. C., effective May 31, having accepted the position of pathologist for the Bayer Company of New York City, manufacturers of the Uspulun products.

Dr. J. C. Walker came to Washington the last week in April for conferences relative to his work on onion and cabbage diseases and to give a talk at the meeting of the National Academy of Sciences on the results to date from the studies on the nature of disease resistance in the onion.

Mr. M. Shapovalov spent the latter part of February on a trip to the West Coast of Mexico for the purpose of studying tomato diseases, particularly western yellow blight.

Miss Minnie W. Taylor, Junior Pathologist in the Office of Investigations in Forest Pathology, Bureau of Plant Industry, U. S. Department of Agriculture, resigned on February 1, 1924, to assume the position of Librarian of the Museum of Natural History at Cleveland, Ohio.

ABSTRACTS OF PAPERS PRESENTED AT THE FIFTH ANNUAL
MEETING OF THE CANADIAN DIVISION OF THE AMERI-
CAN PHYTOPATHOLOGICAL SOCIETY, QUEENS
UNIVERSITY, KINGSTON, ONTARIO,
DECEMBER 20, 21, 1923

Chestnut blight in Ontario. R. E. STONE.

Chestnut blight due to *Endothia parasitica* (Murr.) Ands. & Ands. has made its appearance in Ontario. Many trees in the Niagara Peninsula, near Font Hill, are badly diseased and the disease is spreading. The disease is also present in Norfolk county, near Simcoe. In the last named county twenty-five per cent of the trees are reported diseased. It is probable that the disease will not be checked until all the chestnut timber is gone.

Coryneum twig blight of Manitoba maple. J. E. HOWITT.

The Manitoba maples in the vicinity of the Ontario Agricultural College have many blighted twigs. In May, 1923, Mr. Hurst collected a number of specimens of blighted twigs all affected by the fungus *Coryneum negundinis* B. & C. This fungus is evidently the cause of the blight.

Some problems in forest pathology. A. W. McCALLUM.

A distinction is made between the terms "forest pathology" and "forest mycology," the former being defined as that branch of the science of forestry which is concerned with the study of tree diseases, their causes and their control. Balsam fir grown for pulpwood can be managed on a short rotation and is subject to attack by many fungi. Further, in recent years it has come to be almost as highly regarded as spruce for pulpwood. For these reasons operators desire all available information as to the pathology of this species.

The first step is the identification of the various fungi which cause decay in living trees. This work, though uncompleted, has shown that erroneous ideas have been held as to the etiology of decay in balsam. A large number of trees have been analyzed for decay and from these figures it will be possible to secure data indicating the age to which the stand may be left to grow without risk of serious loss from decay resulting.

The pathological anatomy of tissue produced in Abies balsamica following an attack of the spruce budworm. C. H. McLEOD.

Young shoots of *Abies balsamica*, when attacked by the spruce or balsam budworm, redden and often die. Structural disturbances initiated by the budworms may extend as far as the cambium is affected. The decrease in size of the growth rings is the only change noted macroscopically. There is no brownish zone as in frost injury.

Destruction of the leaves by budworms results in characteristic disturbances of the tissues of the growth rings formed during and immediately following the years of attack. Abnormal tissues vary greatly according to severity of attack and more than one type of abnormal tissue may be found in one section. Abnormal structures are—resin cells or canals, often in a complete ring; broadened or proliferated medullary rays; enlarged tracheids, large cells of parenchyma between medullary rays; groups of large parenchyma cells among tracheids, and parenchyma tracheids.

These abnormalities may appear in any part of the growth ring and all types may appear in the same ring.

A bakery infection with Monilia sitophila. GUILFORD B. REED.

Bread produced from a small bakery in Eastern Ontario when kept for four to five days developed a deep shell pink color through the loaf. The color increased until the loaf was 8 to 10 days old. An infection with the pigmented *Monilia sitophila* proved to be the cause. Spores were widespread in the bakery as a result of the practice of breaking infected loaves. Destruction of all infected material followed by cleaning and liberal application of Javelle water cleared up the trouble.

Mosaic studies IV. B. T. DICKSON.

(a) Mosaic of *Phaseolus sativus*, transmitted through seed, was again evident in Prussian Blue, Golden Vine, Canadian Beauty, Chancellor and White Marrowfat varieties at MacDonald College.

(b) Soy bean mosaic was found for the first time in Quebec.

(c) One case of transmission of tomato mosaic to healthy tomato under cage conditions by the flea beetle (*Epitrix cucumeris*) occurred in July, 1923.

A single case of transmission from *Physalis* sp. to *Browallia* sp. occurred in the author's garden but under uncontrolled conditions.

Experiments in oat smut control in 1923. J. E. HOWITT and R. E. STONE.

Experiments were conducted in co-operation with the Crop Protection Institute of the United States. All experiments were in triplicate on 1/40th acre plots.

Results of experiments are shown in the following table.

Treatment	Germination		Amount of smut	Yield per acre
	In Soil	In Zurich Germinators		
Formaldehyde sprinkle	46	26	Trace	36.94
Formaldehyde spray	98	91	Trace	46.03
Copper carbonate dust, 2 ounces per bushel	97	95.5	1.2	44.86
Copper sulphate and lime dust	94	85.5	3.1	44.61
Copper sulphate dip	88	89	.73	45.89
Check	98	94.5	4.4	44.49

Summary

First—The formaldehyde sprinkle treatment reduced both germination and yield.

Second—The formaldehyde spray almost entirely prevented smut and gave the largest yield of any of the methods.

Third—Neither copper carbonate dust or copper sulphate lime dust were effective in eliminating smut.

Fourth—Copper sulphate dip reduced germination slightly but was effective in the control of smut.

Report of plant disease survey for Canada, 1923. F. L. DRAYTON.

The report covers more or less fully 260 diseases, with reports from 62 collaborators. A brief summary of the prevalence of some diseases of interest:—

Wheat stem rust: caused greater losses than in any year since 1916. In Alberta it was severe but too late to do serious damage. In Saskatchewan, much damage occurred to late crops. In Manitoba losses were estimated at 35,000,000 bushels. In the Eastern

Provinces severe infections occurred locally but losses were not as severe as in the Prairie Provinces.

Clover powdery mildew: widespread, loss is questionable except where clover is grown for seed.

Clover anthracnose (*Gloco sporium caulivorum*): caused the destruction of certain plots at the Central Experimental Farm.

Sclerotinia wilt or drop of sunflowers is widespread and is assuming alarming proportions in parts of Manitoba and Prince Edward Island.

Raspberry mosaic: serious in Manitoba, Ontario, New Brunswick, Prince Edward Island. Becoming common in Quebec and Nova Scotia.

Onion smut: occurs in Winnipeg, Manitoba; Leamington, Ontario; and Island of Montreal, Quebec.

Tobacco mosaic and root-rot: common in Ontario and Quebec.

White Pine Blister Rust occurs as follows:--

On Pines: British Columbia, Ontario, Nova Scotia, New Brunswick and Quebec.

On Ribes: British Columbia, Ontario, Nova Scotia, New Brunswick, Prince Edward Island and Quebec.

Seed treatment for smut control. W. P. FRASER and P. M. SIMMONDS.

This paper describes experiments on smut control with wheat and hull-less oats in co-operation with four of the Dominion Experimental Farms in Saskatchewan and Alberta. Copper carbonate, a mixture of equal parts of copper sulphate and calcium carbonate and sulphur in the form of dusts were used, also solutions of formaldehyde, semesau and chlorophol. All the substances gave good control except sulphur at some stations. Copper carbonate dust was most satisfactory for hull-less oats. The yields were not significant.

"Take-all" of wheat in Western Canada. W. P. FRASER.

Last season a field of Marquis wheat in northern Saskatchewan was found to be rather severely attacked by foot-rot. The field showed many areas of stunted grain with white heads characteristic of "take-all." Abundant mycelium was present on the bases of the stems of the diseased plants, and also perithecia with mature asci. The study of this material showed the fungus to be *Ophobolus caricis* (B. & Br.) Sacc.

Raspberry Diseases. G. H. BERKELEY and A. B. JACKSON.

The average amount of mosaic for the Niagara Peninsula is from fifteen to twenty per cent. There is less in the district around London, Ontario, many of the fields being free from the disease.

Nicotine sulphate may be used to check the spread of the disease. In unsprayed plantations the disease spread 5.3 per cent. In those sprayed twice the spread was only 3.8 per cent. Heavy fertilizing masked the presence of the disease. The chief method of control during the past two years has been the use of certified stock. A number of disease-free plantations have been found, and these together with others, having less than 3 per cent of mosaic furnish satisfactory stock. A grower may use his own stock by selecting only healthy shoots.

Leaf curl in the Niagara Peninsula varies from zero to five per cent. It is apparently on the decrease. Diseased plants are rogued as soon as noticed and the spread of this disease has been greatly checked.

Blue stem of red and black raspberry. G. H. BERKELEY and A. B. JACKSON.

In 1922 the presence of blue stem, as described by Lawrence, was reported on black

raspberries in the Niagara Peninsula. This year we have to report blue stem as prevalent throughout the Peninsula on both black and red raspberries. Three-fourths of the Cuthbert plantations showed the disease to be present, in some cases as high as 10 per cent. Affected plants show the typical blue-stem with accompanying defoliation; bronzing of the tip leaves and the blue discoloration of a portion or all of the stem. The tops become brown and withered. No fruit-bodies have been observed in the field.

Sections of diseased plants show the presence of mycelium in the wood elements. Internal isolations from infected canes give characteristic cultures of *Acrostolagmus caulophagus*, Lawrence.

Strawberry black root. G. H. BERKELEY and A. B. JACKSON.

In the past the cause of this trouble has been put down to winter injury. During the season of 1923 this trouble was fairly general in one or two districts of the Niagara Peninsula. Evidence, mainly of an observational nature has been brought forward which tends to show that there are three types of this black root injury. Further evidence, supported by preliminary inoculation tests, points out the possibility that at least one of these types of injury may be caused by soil bacteria.

Effects of salt and hydrogen-ion concentration upon the growth and structure of certain bacteria and moulds. GUILFORD B. REED.

The growth of *Fibrio comma* in dilute peptone is increased with the addition of NaCl up to 0.2 M. The addition of the salt widens the pH tolerance. Further increase in the concentration of NaCl decreases the growth and decreases the pH tolerance.

In very dilute NaCl and at optimum pH for growth the organisms are small regular cocci and rods, at pH higher or lower than optimum the organisms are larger and at the extremes of pH consist of large rods and yeast-like bodies. In the optimum NaCl concentration for growth the organisms are more nearly typical with less variation in structure at the extremes of pH. In concentrations of NaCl above optimum the organisms are all larger than the normal with conspicuous modifications in structure at the extreme of pH.

The growth of *Oidium lactis* is similarly influenced by salt concentration and pH. At optimum pH and salt concentrations for growth, some hyphae, but mostly yeast-like bodies are produced. At higher or lower pH salt concentration than optimum for growth more hyphae and fewer yeast-like cells are produced. At the extremes of pH and salt concentration only hyphae are produced.

Root rot and blight of canning peas. R. E. STONE.

In certain sections of Ontario peas are extensively grown both for canning purposes and for seed. In some of the pea-growing sections a disease known as root rot and as blight has caused serious loss.

Two fungi are closely associated with the disease both of which are capable of causing trouble. One fungus, a species of *Fusarium*, attacks the roots causing them to rot. The other fungus, a *Pythium* works near the soil surface producing a symptom resembling damping off. A *Rhizoctonia* is often associated with the two fungi just mentioned. The disease is carried over in the soil for several years.

An attempt is being made to secure disease-resistant strains of peas. Last year thirty-four strains were secured through the co-operation of Wisconsin Experiment Station and U. S. Department of Agriculture, and the Dominion Canners Seeds Limited. These strains were planted in a badly infested field.

The check plots and many of the selected strains were total failures. However three strains gave very good yields and two other selections gave fair yields.

The best yielding strains will be tested again and if satisfactory will be propagated.

In the meantime experiments will be carried on to determine the length of time required to render an infested field safe for pea growing.

Metabolism in Botrytis. A. HUNTER and G. H. BERKELEY.

A study of the metabolism of four *Botrytis* forms of the *B. cinerea* group was carried out by analysis for total nitrogen, ammonia N., amino N., sugar content and titratable acidity of the medium along with total N., and dry weight values of the mycelium. The three media used were liquid synthetic media with the nitrogen source the only variable. The results given mainly in graph form show not only important and interesting aspects of metabolism, but in addition, the nature of the graphs clearly points out that two of the four forms are very closely related and comprise a group distinct from the other forms. This same grouping has been obtained from cultural studies under constant temperature conditions. A correlation between physiology and morphology, in so far as grouping of the forms is concerned, has been established.

Results of experiments to prevent potato Rhizoetonia. J. E. HOWITT.

These experiments have been carried on for five years. Each year plots of 1/100 acre were planted in the same field and on the same day. Results are shown by the following table:

Solution	No. of years	Time of immersion	Average amount of Rhizoetonia
1-2000	4	2 hours	10.14 per cent
1-2000	4	3 hours	6.37 per cent
1-1200	4	1 hour	6.97 per cent
Control	4		48.37 per cent
1-500	3	2 hours	.7 per cent
1-500	3	1 hour	none
Control	3		56.9 per cent
1-1000	2	2 hours	11.6 per cent
1-500	2	½ hour	1.65 per cent
Control	2		60.6 per cent

In 1922 all plots were free from Rhizoetonia and this year is not included in the table.

Conclusions

1. In Ontario corrosive sublimate materially reduces the amount of Rhizoetonia.
2. Stronger solutions than usually recommended can be used.
3. Corrosive sublimate, one part to five hundred for one or two hours eliminates Rhizoetonia under soil and climatic conditions occurring at Guelph, Ont.

Stereum sanguinolentum as the cause of "Sapin Rouge" or red heart rot of balsam.

J. H. FAULL and MISS IRENE MOUNCE.

Because spruce is becoming scarce newsprint pulp industries are now using balsam for their supplies of raw material. Diseases of balsam have not been carefully studied. One very important disease of balsam is the trunk disease or heart rot of living trees. Fifty per cent or more of affected stems may be discarded as unmerchantable. The rot extends throughout the length of the trunk down to breast height. French Canadian lumberjacks call these trees "Sapin rouge." The disease has also been called "hemlock

rot of balsam." During 1923 the senior author concentrated on a study of heart rot in the field. These studies showed the association of the fruits of *Stereum sanguinolentum* with this decay. Test tube cultures from the red heart rot made in December, 1922, developed fruits of *Stereum sanguinolentum* in August, 1923.

The fungus fruits abundantly on dead trees and slash, and furnishes further reason for slash disposal. It is possible that living trees with this heart rot may be utilized for newspaper pulp.

The aecial stage of Hyalopsora aspidiotus (Peck) P. Magnus. J. H. FAULL and G. D. DARKER.

Ten species of *Hyalopsora* (Magnus, 1901) are reported by Sydow, all known from telial or uredinial stages only. *H. aspidiotus* (*Uredo polypodii* var. *Polypodii-dryopteridis* Mougl. et Nestl. 1815) occurs frequently in some localities on *Phegopteris dryopteris* in Europe and North America. Foliage of *Abies balsamea* bearing pycnia on two-year-old needles, and peridermia and pycnia on needles in their third year were found by H. P. Bell and J. H. Faull in Ontario and Quebec, 1920, 1922 and 1923, and associated with *P. dryopteris* carrying *Hyalopsora* rust. Dr. Bell named the rust on balsam *Peridermium pycnoconspicuum*. Inoculations by Dr. Bell from the balsam to the fern, in 1922, indicate that *H. aspidiotus* and *P. pycnoconspicuum* were stages of the same rust. In 1923 inoculations by Faull and Darker confirm these conclusions. Twenty fronds were inoculated, thirty controls were kept. Lesions developed on all the inoculated fronds (249 primary infections in all). Uredinial pustules formed on most of them (283 pustules in all). The controls remained free, the period of incubation was 22 days, June 20th to July 12th.

Smut control experiments in hull-less oats during 1923. B. T. DICKSON, R. SUMMERBY and J. G. COULSON.

Plots were replicated four times. The results indicate that copper carbonate dust treatment is efficient in control and simple in application. The table summarizes the results at MacDonald College, Quebec, Canada.

Treatment	Germination in lab.	Total culm count	% Smut by total head count	Yield in B.P.A.	P. L.
Formalin sprinkle	77	4128	1.8	33.54	± 2.38
CuSO ₄ Dip	83	3662	0.38	31.60	± 1.74
No treatment	93	6628	72.8	12.48	± 0.64
No. CuCO ₃ Dust	93	3832	1.5	36.62	± 3.53
No treatment	93	7417	70.0	12.15	± 0.64
No. CuSO ₄ lime dust	80	4404	1.45	38.56	± 3.28

The June number of Phytopathology was issued June 27.

PHYTOPATHOLOGY

VOLUME XIV

NUMBER 8

AUGUST, 1924

STUDIES ON A LEAF SPOT OF PHASEOLUS AUREUS NEW TO THE PHILIPPINE ISLANDS

COLIN G. WELLES

WITH PLATE XXIV AND THREE FIGURES IN THE TEXT

A serious leaf spotting of *Phaseolus aureus* Roxb. has been under observation at the College of Agriculture, Los Baños, P. I., since September 1, 1921. In the beginning the spots appeared only on the older leaves but later they spread, until on November first the plants were nearly defoliated and stems and pods were seriously affected. The development of the disease was phenomenal due to the heavy rains which commenced about October fifteenth.

Studies were made on the casual organism and the fungus was identified as *Cercospora cruenta* Sacc. While this fungus and closely related fungi are widely distributed in many parts of the Orient and America on beans, it has never before been reported from the Philippine Islands, nor has it been reported on pods of any of the species of *Phaseolus*, *Dolichos*, or *Vigna* on which it has been formerly noted.

Many species of cultivated beans are parasitized by *Cercospora* in the Philippine Islands. The relationship of these organisms is entirely unknown. The host reactions in the different cases are not at all similar. In fact there is no symptomatic ground by which the parasites may be differentiated and no work has been performed with the causal organisms which has revealed any of the fundamental physiological similarities or differences which necessarily exist.

REVIEW OF LITERATURE

Butler (1, 261-2.) in a brief statement presents the possible relationship between the various *Cercosporas* which he has observed on different species of beans in India. These comparisons are based entirely on morphological differences and variations in host reaction. He concludes that *C. cruenta*, which appears to be the same as the organism under consideration, is probably identical with *C. canescens*, reported from the United States and *C. vignae*, reported from Java. He also states that there is probably no difference between *C. cruenta* and *C. dolichi*. With the exception of *C. dolichi*

none of the organisms discussed by Butler have been previously reported from the Philippine Islands.

He states further that *C. cruenta* parasitizes the mung bean (*Phaseolus radiatus* Linn.¹) in India.

Reinking (2, 248), reported a *Cercospora* leaf spot of *Vigna sinensis* from the Philippines but included with the note very little descriptive matter. Concerning the symptoms of the disease he says:

“Leaves may be spotted with definite circular spots from 1 to 3 millimeters in diameter. Spots have gray centers with purplish borders.”

He states further that the organism responsible for the disease is a *Cercospora* but includes no spore description other than that “the conidia are tapering and usually have four to six cells.”

The following measurements were made from an illustration drawn to scale which accompanied Reinking's report: Conidia 21 to 70 microns long by 3.5 to 7 microns wide and conidiophores 70 to 80 microns long by 3.5 to 7 microns in width.

THE PHILIPPINE DISEASE

The plants in the field which has been under observation showed pronounced diseased conditions. The beans were planted broadcast and, as a result, the stand was very thick.

The diseased plants, in this case nearly one hundred per cent, appeared defoliated and where the leaves persisted they were sickly and severely spotted. The field had the appearance of being burned excepting in places where the leaves had escaped with a thorough scorching.

SYMPTOMS

The disease appears on leaves, pods and stems of *Phaseolus aureus* Roxb.
On the leaves:

The leaf spots are more or less circular and do not exhibit the angular form mentioned by Butler (1, 261-2). The lesions are purplish-red sometimes showing no differentiation into zones but commonly having light gray centers. The grayish centers are not confined to large lesions but are exhibited as well in lesions not more than one millimeter in diameter.

The lesions vary in size from .5 to 4 millimeters in diameter, the average falling between 3 and 4 millimeters.

In a very few instances the diseased areas coalesce and form large irregular patches limited by the leaf veins.

¹ The following note concerning the taxonomy of this plant is inserted so that confusion of host plants will be avoided to some extent. *Phaseolus aureus* Roxb. is synonymous with *Phaseolus radiatus*, the non-Linnaean species. *Phaseolus radiatus*, the Linnaean species, is commonly known as *urd* in India according to Watt (4, 880-2).

The lesions while very pronounced on the upper surface are barely discernible on the lower surface of the leaf except in advanced stages.

On the pods:

Pods which have reached a length of about 6 centimeters are seriously attacked. The younger pods appear to be free from the disease.

The pods show all degrees of attack from a few spots on each to a solid blackening and killing of the entire growth. Both young and old spots are dark purple.

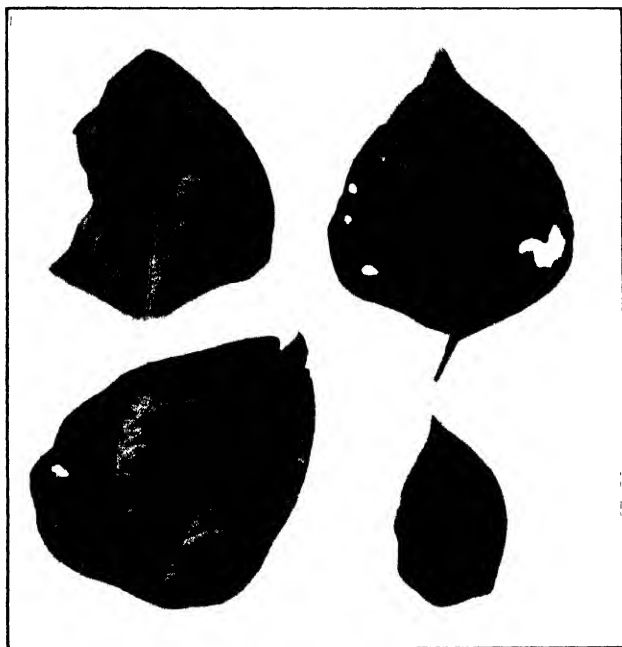


FIG. 1. Diseased leaves showing typical spots on *Phaseolus aureus* Roxb. caused by *Cercospora cruenta* Sacc.

In very severe attacks the seeds within are parasitized and become shrivelled and darkened.

On the stems:

The lesions on the stems are not so common as those on the leaves and pods, yet they may be found in considerable abundance.

The young stem lesions first appear as slightly darkened areas with the long axis of the lesion parallel to the long axis of the stem. Later the spots become darker and finally of a purplish color. Frequently they reach a length of 4 centimeters in the longest dimension.

DISTRIBUTION

The distribution of this disease in the Philippine Islands is wholly unknown. No previous mention of its appearance has been made to the writer's knowledge and at present it appears to be confined to plantings at the College of Agriculture, Los Baños.

ECONOMIC IMPORTANCE

The destruction due to this disease is remarkable. One hundred per cent of the leaves, both young and old, were attacked and exhibited from 10 to 50 lesions per leaf.

In one portion of the planting which embraced about one hectare, many leaves had fallen and frequently but two or three remained attached to each plant. In other portions the attack was less serious or at least the result was less serious, for the leaves persisted although thickly covered with diseased spots.

The pods as well as the leaves were seriously parasitized especially if they had developed to any degree of maturity. Seventy-five per cent of the pods containing partially formed seeds were attacked but young pods remained uninjured. In a few cases seeds developed to maturity but in the main they dried up either due to the diseased condition of the pod or less frequently due to invasion by the causal organism.

The spots on the stem were not so numerous as those on the leaves and pods and the direct damage by them was of little importance.

CAUSAL ORGANISM

The organism responsible for the leaf spot disease of *Phaseolus aureus* has been identified as *Cercospora cruenta* Sacc. which causes leaf spots on various species of beans. Butler (1) reports as follows concerning *Cercospora cruenta*:

"The conidiophores emerge in clusters through the stomata. They are brown, septate, with knee-bends marking the insertion of fallen spores, as is usual in this genus, about 50 to 100 micra long by 4 to 6 micra broad. The conidia are borne terminally but the stalk continues to grow at one side so that the spores are pushed over and fall off. They are variable in size, from 50 to 140 by 4 to 5 micra, elongated, tapering above, with 2 to 8 septa, straight or slightly curved, and almost colorless."

The conidiophores of the Philippine organism measure from 55 to 91 microns in length and are 3 to 5 septate. They are typical of *Cercospora* conidiophores arising from stomata.

The conidia are hyaline, straight or slightly curved, obelavate, and measure from 51 to 135 microns in length by 6 to 9 microns in width, and are 3 to 7 septate.

INOCULATION EXPERIMENTS

Pure cultures of *Cercospora lussoniensis* Sacc. were obtained from *Phaseolus lunatus*. Inoculations with these cultures were made on *Phaseolus aureus*. Very interesting results were obtained which appear to bear directly on the classification of these two supposedly distinct parasites.

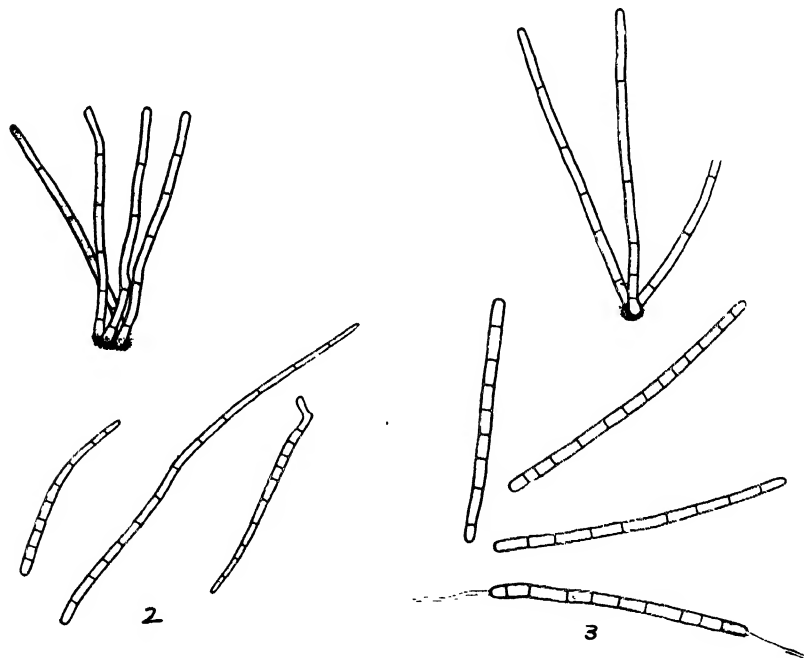


FIG. 2. Conidiophores and conidia of *Cercospora cruenta* Sacc. from *P. aureus* Roxb. Drawn by C. C. Naeve with the aid of camera lucida ($\times 600$).

FIG. 3. Conidiophores and conidia of *Cercospora lussoniensis* Sacc. from artificial inoculation on *Phaseolus aureus* Roxb. Drawn by C. C. Naeve with the aid of the camera lucida ($\times 600$).

The inoculations were made in the field on young leaves in the following manner: Leaves were washed with mercuric chloride, 1-1000, and rinsed with sterile water. A mass of spores and mycelium was then removed from a pure culture and placed on the upper surface of the leaf. A wax-paper bag containing a small amount of water-saturated cotton was then tied over the leaf.

Observations at the end of one day revealed no lesion. At the end of the second day, however, a distinct, small lesion was found. After four days the leaves were removed and it was found that they bore mature

conidia on the under surface of the leaf. That the spores were borne on the under surface when the inoculation was made on the upper side of the leaf precludes all possibility of observing spores formed by the original inoculum.

The conidiophores measured 78 to 99 microns in length and exhibited 4 or 5 septations.

The conidia were nearly hyaline and measured 100 to 110 microns in length and exhibited from 8 to 11 septations.

The lesions did not appear similar to those which are naturally found on *P. aureus*. They were ashen gray in the center, yellow bordered.

Whether these two fungi are identical or not is a matter of speculation but it has been shown previously that there is a common variation in host reaction, at least with different species of host plants. The appearance of a lesion in a large measure, is due to the reaction of the host to the irritant rather than to any particular property of the causal factor itself.

The following table gives the comparative conidiophore and conidial measurements of *C. lussoniensis* on *P. lunatus*, of *C. lussoniensis* and *C. cruenta* on *P. aureus*.

TABLE 1.—Comparative conidiophore and conidial measurements on *Phascolus lunatus* and *Phascolus aureus*.

	Conidiophores		Conidia	
	Length	Septation	Length	Septation
<i>C. lussoniensis</i> on <i>P. lunatus</i>	90-221 *28-35	3-6	59-101 *35-45	2-9 *3
** <i>Cercospora</i> sp. on <i>Vigna sinensis</i>	70-80	8-9	21-70	3-5
<i>C. lussoniensis</i> on <i>P. lunatus</i> (Inoculation)	78-98	4-5	100-110	8-11
<i>C. cruenta</i> on <i>P. aureus</i>	59-91 ***50-100	3-5	53-153 ***50-140	3-7 ***2-8

*After Saccardo, ** Reinking, and *** Butler.

The conidiophore and conidial measurements as reported by Saccardo in his original description and those obtained from Los Baños material show a striking discrepancy. The season of the year when the Saccardo material was collected is not recorded but it is likely that it was obtained during a period of rather slight precipitation. The measurements which were made by the writer were obtained from material collected during the rainy

season. When collected during the drier seasons of the year the lengths are considerably less.

The conidial measurements obtained from inoculation of *P. aureus* with *C. lussoniensis* are not sufficiently different from those obtained on the same host from natural field infection to make it possible to state that the organisms are morphologically distinct. The writer has found that moisture effects the length of conidiophores and conidia to a great extent and so it is very understandable that the larger size of the spores obtained from artificial inoculation may be due to the higher moisture which is present under conditions of artificial inoculation.

CONTROL

Several experiments have been performed in an attempt to control *Cercospora* diseases of *Coffea* sp., *Averrhoa carambola*, and *Solanum melongena*. In each instance successful results were obtained and in experiments where Bordeaux mixture was applied every two weeks for no less than five applications, there was nearly absolute control. As the leaf spot of *Phaseolus aureus* is caused by a *Cercospora* and as the disease parallels those experimented with it is reasonable to conclude that Bordeaux mixture when applied at the intervals suggested above, will successfully control the disease.

This recourse, however, is not recommended for Bordeaux mixture required in spraying a crop such as the one under discussion is very expensive and the cost involved would be in excess of the value gained by the increase in yield.

Butler (1) suggests the development of resistant varieties. This solution must be accomplished if present cultural practices are not abandoned.

The disease on *Phaseolus aureus* has been noticed only during periods of heavy rains. If this is always true, a possible solution of control, lies in making plantings at that time of the year when rainfall is slight. These beans grow well in any season.

SUMMARY

1. A leaf spot of *Phaseolus aureus* has appeared in the plantings at the College of Agriculture, Las Baños, P. I.

2. The disease appears to be caused by *Cercospora cruenta* Sacc., which is responsible for leaf spot diseases of various species of beans in the United States, India, Ceylon, and China.

3. The disease is very serious and inhibits pod development due to defoliation or partial destruction of the photosynthetic area of leaves. About 100 per cent of the leaves and 75 per cent of the older pods are attacked. Stems are less frequently parasitized.

4. Inoculation experiments with pure cultures of *Cercospora lussoniensis* on *Phaseolus aureus* produces symptoms slightly different from those caused by *Cercospora cruenta*. Conidiophores and conidia were of approximately the same length and appeared very similar. A close relationship between these two species of *Cercospora* is suggested.

5. While it is believed that Bordeaux mixture will successfully control the disease, it is not recommended because of the cost involved. Resistant varieties and a change in cultural practice are suggested as possible means of combatting the disease.

UNIVERSITY OF WISCONSIN.

LITERATURE CITED

1. BUTLER, E. J. Fungi and disease in plants. 547 p., 206 fig. Calcutta. 1918.
2. REINKING, O. A. Philippine economic-plant diseases. Philippine Jour. Sci. Ser. A, 13: 165-274. 22 pl., 43 fig. 1918.
3. SACCARDO, P. A. Notae mycologicae. Ann. Mycol. 9: 249-257. 1911.
4. WATT, GEORGE. The commercial products of India. 1189 p. London. 1908.

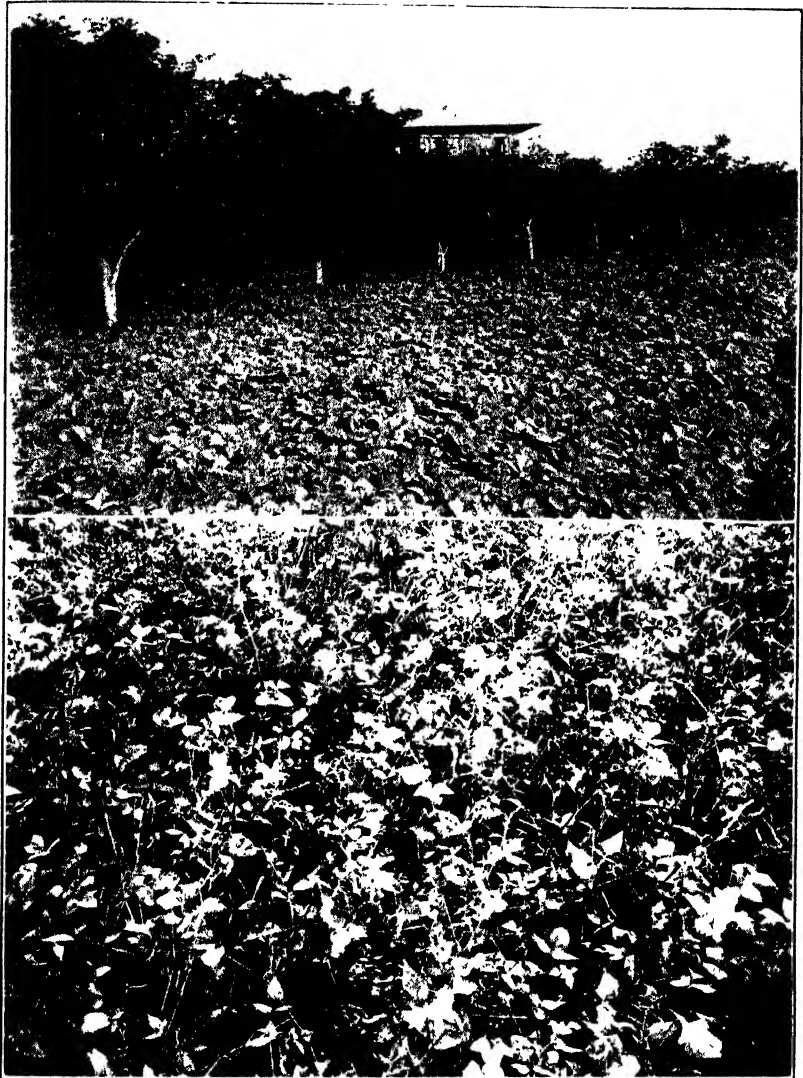


FIG. A. (Upper.) Photograph of a field of beans (*Phaseolus aureus*) taken about the first of September, 1921. This photograph was taken to demonstrate the vigor and prolificness with which this crop grows in the Philippines.

B. (Lower.) A photograph of a small section of the same field made about the first of November of the same year. The plants are nearly defoliated. The pods were seriously diseased and the entire crop was an utter loss.

SIMULTANEOUS SURVEYS FOR STEM RUST: A METHOD OF LOCATING SOURCES OF INOCULUM

E. M. FREEMAN AND L. W. MELANDER

WITH ONE FIGURE IN THE TEXT

INTRODUCTION

It is obvious to anyone familiar with the details of operation in the barberry eradication campaign that one of the most difficult problems is to locate the last few bushes, those few stragglers or seedlings that have escaped all efforts to find them. It is highly important not only that these bushes finally be located and destroyed but that they be located and destroyed at the earliest possible moment. There is always the potential factor of an early start of the rust from such bushes and furthermore there is the certainty that these bushes, if not eradicated, will spread barberries to the adjacent territory through seed formation. As long as such bushes remain, the final effect of eradication can neither be determined nor realized.

It also is obvious that a mere repetition of the original methods, *viz.*, survey and resurvey, would be expensive and could not hope to give complete eradication in the immediate future. Numerous cases have been recorded in the present campaign in various states where barberries have been located through the local epidemics which they have produced. Can this method now be applied generally in those large regions or states where the whole area has been completely surveyed and resurveyed? If such is the case it would offer an inexpensive method of eradication and at the same time a procedure convincing to the farmer and the public at large.

METHOD SUGGESTED

The following suggestions are made in order to stimulate a study and trial of such a method for the "clean-up" in barberry eradication. It is proposed that simultaneous surveys be made over certain areas of fairly uniform nature at a time in the year when the incipient local epidemics can be detected and before these local epidemics have had time to coalesce or to become general. If such surveys can be made with sufficient thoroughness and over sufficiently large areas it seems reasonable to assume that the remaining barberry bushes may be rapidly located. It also is possible that the findings may follow a descending order of the rust-producing potentialities of the bushes. That is, the larger plantings or bushes and those bushes in strategic positions for rust production may be expected to be among the first bushes found.

The suggested method would require a considerable force of men available in a given area on the same day or during a short period of days.

The time for making the surveys would need to be carefully selected for each area and should coincide with the occurrence of the local epidemics but should occur before the infection in the area is general. County agents and others interested in the rust problem probably could be enlisted for the work. The survey would include the collection of as many typical samples of small grains in as many localities as possible so as to cover thoroughly the whole area. No search need be made at this time for barberry bushes. The samples, marked accurately for locality, would be assembled at one central point, the rust percentage determined, and the areas represented would be mapped. Any areas consistently rusted could then be further investigated by the eradication forces for the location of possible bushes. The records for one year would be of great value in the succeeding year if rust-producing bushes escaped detection in the first year.

Perhaps the most puzzling detail of the suggested surveys would be the determination of the size of the area to be covered. If, for instance, the area included the southern half of the State of Minnesota with a corresponding area extended through the State of South Dakota, the field organization would have to be large and the survey could not be expected to be as complete as in a smaller area. Small local epidemics might easily be overlooked but, on the other hand, large sources of infection might perhaps be located and such areas could then be thoroughly studied. If the surveys were confined to a small group of counties the chances for the detection of small local epidemics would be better. The area covered, however, would be comparatively small and progress would be slow. An experimental test of both methods undoubtedly would yield valuable results for future use in barberry eradication.

The simultaneous surveys method is of course not new. It has been used in Blister Rust Eradication by Spaulding (U. S. D. A. Bull. 116, pp. 5), and others. It does not follow that it can certainly be applied to barberry eradication in all areas such as the great plains region. If, however, it can be used it may furnish a much needed means for the final eradication process, and it is of utmost importance that the barberry eradication be completed at the earliest possible moment.

RESULTS OF CLAY COUNTY SURVEYS

In order to test the possibilities as well as the numerous problems involved, simultaneous surveys were made on July 30, 1923, in Clay County, Minnesota, where black stem rust is a destructive disease of wheat and other small grains. At this time a fairly severe epidemic was general in northern Minnesota and North Dakota. Clay County measures 30 miles east and west by 36 miles north and south. It was separated into five areas as shown by dotted lines in figure 1. Each of these areas was surveyed on the same day by one crew of two experienced men. Each crew spent the whole day in a trip through its assigned area and collected typical samples

of rusted Marquis wheat (the standard wheat of this section) from as many fields as possible. A careful record of the location of each collection was made and notes were taken also on the topography, weeds, and other factors which might influence the severity of rust. The collectors also recorded their estimate of the percentage of rust in each field from which samples

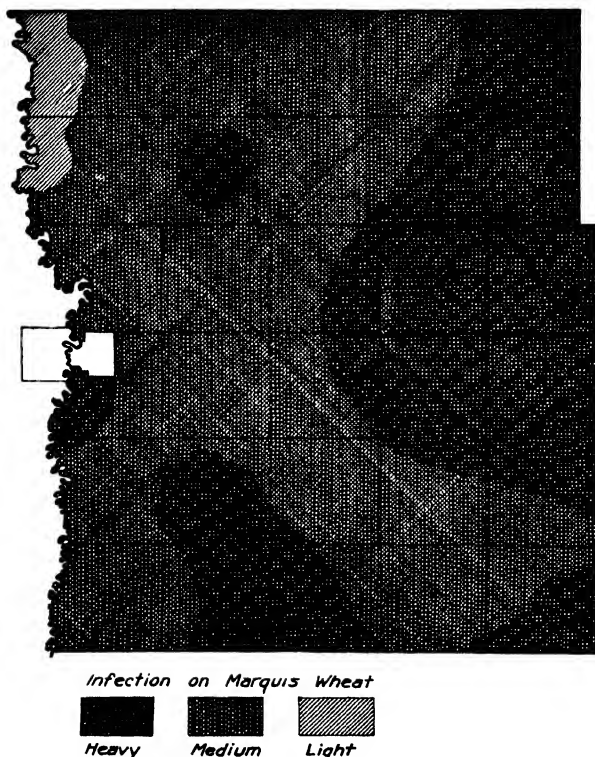


FIG. 1. Map of Clay County, Minn., showing relative severity of *Puccinia graminis tritici* on Marquis wheat, July 30, 1923.

were taken. The samples were brought to one central point and an estimate of each sample was made independently by each of three men who had had long experience in cereal-rust investigations. The estimates of these men, together with the field estimates of the collectors, were averaged and recorded as a basis for plotting the map (Fig. 1).

In all, 173 Marquis wheat fields were examined. The average mean percentage of stem rust was $39.86 \pm .91$ per cent. The rust estimates were divided into three classes, 0 to 20 per cent indicating light infection, 20 to 50 per cent moderate infection, and over 50 per cent, heavy infection. These classes were used in plotting the relative degrees of infection on the map.

It is obvious that there were consistent differences in the severity of rust in the different areas of the county. It was not the object of the surveys to determine the probable location of barberries, inasmuch as the rust infection had become general over the whole region and the grain was about to be cut. It was realized that such surveys for the location of barberries would have to be made at least several weeks earlier. It is a significant fact, however, that even at such a late date as the opening of the wheat harvest there are considerable and consistent differences in the rust severity in such an area as that examined where the conditions are as uniform as one could reasonably expect to find. Clay County lies in the Red River Valley and consists almost entirely of very flat prairie land with uniform soil. The types of farming, varieties grown, and other conditions also are quite uniform. While no correlation can safely be drawn in these surveys between rust infections and barberry locations, it is not impossible that presence of barberries might satisfactorily explain the rust differences, if all locations were known. The immediate point of interest is that with a well-developed and widespread general epidemic in an area of remarkably uniform conditions, simultaneous surveys showed consistent local differences in the rust attack. The results at least lend encouragement to the suggestion for simultaneous surveys in the location of barberries.

CEREAL AND GRASS INDICATORS

If simultaneous surveys of grain rust are to be undertaken for locating the straggling barberries, the cereal and grass hosts also should be carefully considered. Some results obtained in Minnesota during the summer of 1923 indicate that, at least in some years, winter rye may be a valuable indicator. The occurrence of the black stem rust on rye has been successfully used to locate barberries. Inasmuch as quack grass is so uniformly distributed and so abundant in the upper Mississippi Valley, there usually exists abundant teliospore inoculum of *Puccinia graminis secalis*. Moreover, the complication of windblown urediniospores from the South is possibly less in rye than in wheat as rye is grown only locally south of Minnesota and Wisconsin. The primary source of the rye rust in a given locality probably is more frequently confined to the barberry than is the case in wheat. If this be true, rye may be found a valuable indicator of barberry locations. The possible use of *Agropyron repens*, *Hordeum jubatum*, and other grasses as indicators ought also to be kept in mind in solving the problems of the possible use of the simultaneous surveys in locating scattered barberry bushes.

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RUST RESISTANCE IN TIMOTHY

H. D. BARKER AND H. K. HAYES^{1 2}

WITH ONE FIGURE IN THE TEXT

INTRODUCTION

Hayes and Stakman (6)³ have pointed out the desirability and possibility of developing varieties of timothy resistant to the timothy rust, *Puccinia graminis phleipratensis* (E. and H.) Stak. and Piem. But it is not known whether this rust form consists of several parasitic strains. Since the occurrence of such strains has been shown to be important in the problem of developing varieties of cereals resistant to stem rust, it seemed desirable to investigate this phase of the problem of developing resistant varieties of timothy. Furthermore, it is clear from the work of Biffen (2), Pole Evans (3), Hayes, Parker and Kurtzweil (5), Aamodt (1), and others, that the mode of inheritance of rust resistance is not the same in all cases. It is highly desirable, therefore, to obtain data on the mode of inheritance of resistance to timothy rust. The present paper, therefore, concerns itself largely with these phases of the problem.

MATERIALS AND METHODS

In 1916 a timothy nursery was started on University Farm, St. Paul. Eleven of the better Cornell selections and six of the better Minnesota selections were planted. Each selection was studied by the individual plant method in 1917 and data were taken on height of plant, erectness, length of head, number of tillers, yield of hay, and rust resistance. The results of this study for 1917 have been published (6).

The winter of 1917-18 was very severe and almost all the plants in the entire nursery winter-killed. In the fall of 1918, open pollinated seed was saved individually from several plants which survived. The seed was planted in the greenhouse in the spring of 1919 and 88 seedlings of each selection were transplanted in the field. They were planted in rows 3 feet apart, the plants being spaced 12 inches apart in the row. The single row plots were replicated twice. During three seasons data were obtained on yield, growth habit, etc.

¹ Published with the approval of the Director as Paper No. 475 of the Journal Series of the Minnesota Agricultural Experiment Station.

² The work was done as a part of a project on the production of disease-resistant varieties of field crops carried on jointly by the Section of Plant Pathology and the Section of Plant Breeding of the Department of Agriculture of the University of Minnesota.

³ Reference by number to "Literature Cited," page 370.

In 1919 a heavy rust epidemic was induced by spraying with uredinio-spores collected near St. Paul, and the resistant plants in five of the most promising selections were increased in isolated plots. Several individual plants, with varying degrees of rust resistance, were selected, and 25 bulblets from each were propagated in the greenhouse. These clonal lines were used as possible differential hosts in determining the presence of biologic forms of timothy rust, and self-fertilized lines and crosses were used for studying the inheritance of certain characters.

Some of the effects of self-fertilization and the method of securing self-fertilized seed have been described previously by Hayes and Barker (4). Crosses were obtained in somewhat the same manner. Three plants of each of two clonal lines were separated from other timothy plants in the greenhouse by means of cheese cloth partitions. This was repeated in the field by placing the same number of plants in isolated groups in the small grain nursery at some distance from other timothy plants. Only those plants of the two clonal lines to be crossed were placed together. Since certain lines proved to be almost completely self sterile, it may be presumed for practical purposes that any seed set by such lines are the result of cross fertilization. The crosses studied are obtained from seed produced in the crossing plot from self sterile lines.

EXPERIMENTAL RESULTS

Table 1 presents data on the various lines, each of which is the progeny of a single open pollinated plant which survived the winter of 1917-18. A few lines, for example T 1 and T 11, were almost completely susceptible, while there were no lines which appeared to be completely resistant. There was some evidence that resistance might be a Mendelian dominant.

As previously described, a number of clonal lines were established by propagating individual plants vegetatively. For instance, clonal line T 30-30-9 was obtained from culture No. T 30 (a selection from Cornell No. 1777), row 30, plant No. 9.

Stakman and Piemeisel (9), Stakman and Levine (10, 11), and others, have demonstrated that *Puccinia graminis tritici* Erikss. and Henn. in reality consists of many biologic forms which differ in their pathogenicity for certain varieties of wheat. This has shown that the production of varieties of wheat resistant to stem rust is a complex problem. Stakman, Levine and Bailey (12) have shown that *P. graminis avenae* likewise consists of several forms or strains. In order to ascertain whether the same might be true of *P. graminis phleipratensis*, several clonal lines showing varying degrees of susceptibility to rust were used as possible differential hosts and inoculated with collections of timothy rust from various localities in the United States and Canada. For this purpose clonal lines have certain

TABLE 1.--*Nursery test of rust resistance in timothy in relation to other characters*

Culture No.	Source of seed; individual plant selected in fall of 1918 from	Total yield in grams 1919-1921 inclusive	Growth habit	Rust reaction in 1919 under epidemic conditions		
				Resistant	Intermediate	Susceptible
T 1	Minn. Selection from L. L. May and Company	17570	U to P ²		1	88
T 2	do	14880	do	2		88
T 3	do	15357	U	3		87
T 4	do	16605	U to P	4		86
T 5	Minn. Selection from U. S. Dept.	17486	U	4		86
T 6	do	16193	U	4		86
T 7 ¹	do	18093	U to P	20		60
T 8	do	11829	U	6	1	83
T 9	do	15231	U	10		70
T 10	do	15033	U	4		86
T 11	do	16290	U	1		89
T 12	Cornell No. 1620	16876	U to P	27		62
T 13	do	17231	U	46		34
T 14	do	18185	U to P	25		63
T 15	do	16250	U	14		74
T 16	do	17698	U to P	31		58
T 17 ¹	do	18596	U to P	61		28
T 18	Cornell No. 1630	17483	P	62		27
T 19	do	15288	U	26		62
T 20	do	15708	U to P	48	1	38
T 21 ¹	Cornell No. 1635	18527	U to P	58		24
T 22	Cornell No. 1676	17900	P to U	69		20
T 23	Cornell No. 1671	16982	U to P	61		29
T 24	do	17327	U to P	60		28
T 25	Cornell No. 1715	15680	U to P	31		56
T 26	Cornell No. 1743	17276	U to P	57		32
T 27	do	20082	P to U	55		32
T 28 ¹	Cornell No. 1777	20428	U to P	83		17
T 29	do	17736	U to P	28		60
T 30	do	18545	P to U	47		33
T 31	Cornell No. 3230	17129	U to P	50		37
T 32	do	16092	U to P	48		31
T 33 ¹	N. King Co. Sterling Commer.	16837	U to P	24		65
T 34	Cornell No. 1611	6359	U	74		8

¹ Rust resistant plants in these selections were given Minnesota numbers and increased in isolated plats for further tests.

² U = upright; P = procumbent; U to P = approaching upright; P to U = approaching procumbent.

advantages and certain disadvantages. Vegetative propagation eliminates the possibility of variable results due to natural crossing or mechanical mixture of seed. This is perhaps more than offset by the variable growth conditions at the time of inoculation. Seedlings may be inoculated at approximately the same stage of growth; it is more difficult to get plants

of a clonal line of timothy at the same stage of growth. The vegetative condition and vigor of the plant modified the character of the uredinia produced to a marked degree. In addition to this, the rust classes as recognized by Stakman and Levine (10) for stem rust of wheat are not so sharply defined on timothy. In no case, however, did a resistant plant become completely susceptible, nor did the susceptible ones become resistant. The results presented in table 2 are based on the average type of infection for a given strain of rust on the clonal line concerned. Certain collections of rust were lost, due to adverse conditions at the time of transfer, before they could be tried on all clonal lines. In these cases, not all of the observations are based on repeated inoculations. It was thought that since these, on the basis of the observations made, were in general conformity with those collections upon which more complete data were obtained, they might all be presented for whatever value they may possess.

TABLE 2.—*Inoculation experiments to determine the presence of biologic forms of Puccinia graminis phleopratinensis (E. and H.) Stak. and Picm.*

Rust collection ¹ from	Type of rust reaction ² on																
	T 1-1-26	T 30-30-9	T 30-30-21	T 30-43-23	T 31-31-5	T 31-31-22	T 31-44-1	T 31-47-11	T 31-47-18	T 32-32-26	T 32-32-29	T 32-32-30	T 32-45-14	T 32-45-20	T 32-45-27	T 32-45-27	T 32-45-27
Edmonton, Alta.	4	1	2	2	2	2	4	2	2	2	1	2	2	2	2	2	1
Courtenay, B. C.					1							2					
Lafayette, Ind.	4			2	2				2	3	2	2	2	2	2	2	
Ithaca, N. Y.	4	1	3	2	1	2	3	2	2	2	1	1	2	2	2	2	2
Loweville, N. Y.	4				2				1			2				2	
Fens, Minn.	4	2	2	3	2	2			1	2	2	1	2	1			3
Hopkins, Minn.	4	2	2	2	2					1	1	2	2		2	2	
St. Paul, Minn.	4	2	2	2	2	2	3	2	2	2	2	2	2	2	1	2	
Field test, 1919 (St. Paul)	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

¹ Rust collections from Courtenay and from Edmonton were furnished by Dr. E. C. Stakman, from Lafayette by Dr. E. B. Mains, from Ithaca and Loweville by Dr. R. S. Kirby.

² The symbols used to express types of reaction are adopted from those used by Stakman and Levine (10). Since, however, hypersensitiveness and chlorosis are not so sharply defined in timothy as in wheat, more emphasis is placed on size of uredinia. In the field tests the plants are listed as susceptible or resistant.

From table 2 it appears probable that, on the differential hosts inoculated, the various collections of rust are practically identical. While this test does not prove that biologic specialization does not occur in *P. graminis*

phleipratensis, it indicates that these clonal lines probably would be highly resistant in widely separate localities.

More extensive tests should be made for the presence of biologic specialization in timothy rust. If none is found in this form, it may be quite significant with respect to the origin of biologic forms, because this rust apparently cannot produce accia on barberry (7, 8).

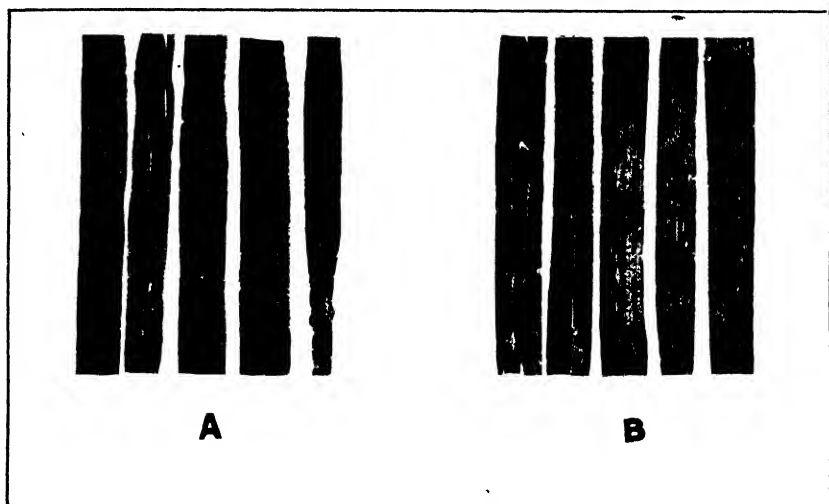


FIG. 1. Illustrations of rust-resistance and rust-susceptibility of timothy plants:
A—Various types of infection which were recorded as susceptible.
B—Various types of infection which were recorded as resistant.

Note that very sharp hypersensitive areas do not appear in timothy. Resistant plants give small pustules which are not confluent. Marked chlorosis is usually, but not always, associated with resistance. This chlorosis may approach distinct hypersensitivity.

The seed of various self-fertilized clonal lines and of crosses between certain of these clones were secured by the plan described under Materials and Methods. The selections were planted in the greenhouse in the spring of 1922 and inoculated in the seedling stage with urediniospores collected near St. Paul. Ten days after inoculation, notes were taken on each seedling plant. The character of the rust reaction upon which these were classified as resistant, or susceptible, are illustrated in figure 1. The results of the inoculations are summarized in table 3:

The results presented in table 3 indicate quite clearly that the inheritance of rust resistance is here dependent upon a single pair of genetic factors, giving approximately three resistant plants to one susceptible. Resistance is clearly dominant, because, although there was considerable

TABLE 3.—*Inheritance of rust resistance in timothy on the basis of inoculation results obtained in the greenhouse in the spring of 1922*

Group No.	Selection or cross	Source of seed	No. of plants		Expected ratio on the basis of			Observed ratio R : S	P. E.	Probability
			Total	R	S	3 R to 1 S	1 R to 1 S				R	S
1	T 30-30-9	G ¹	140	118	22	105	35	3.37 : 0.63	0.10	1 : 78.37
2	do	F	154	105	49	115.5	38.5	2.74 : 1.26	0.09	1 : 18.80
3	T 30-30-21	G	27	23	4	20.25	6.75	3.41 : 0.59	0.22	1 : 4.64
4	do	F	153	92	61	114.75	38.25	2.41 : 1.59	0.09	1 : 19230.00
5	T 30-63-23	G	75	63	12	56.25	18.75	1.20 : 0.80	0.05	1 : 142.26
6	T 31-31-5	G	90	79	11	67.5	22.5	3.36 : 0.64	0.14	1 : 11.58
7	T 31-64-1	G	60	46	14	45	15	3.48 : 0.52	0.12	1 : 142.26
8	do	F	158	105	53	118.5	39.5	3.07 : 0.93	0.14	1 : 1
9	T 31-97-11	G	180	134	46	135	45	2.66 : 1.34	0.09	1 : 64.79
10	do	F	144	107	37	108	36	2.98 : 1.02	0.08	1 : 1
11	T 31-97-18	G	59	59				2.97 : 1.03	0.10	1 : 1
12	T 32-32-30	F	27	17	8	20.25	6.75	2.82 : 1.18	0.22	1 : 1
13	T 32-65-29	G	3	3						
14	T 32-98-24	G	16	11	5	12	4	2.75 : 1.25	0.29	1 : 1
15	T 32-98-27	G	18	18						
16	T 1-1-26	G	2							
17	T 1-1-26	G								
	x									
18	T 32-32-30 T 32-65-14	F	196	100	96		98 98	1.02 : 0.98	0.05	1 : 1
	x									
19 ²	T 32-32-30	F	47	38	9	35.25	11.75	3.24 : 0.76	0.17	1 : 1.9
20 ³	N. K. Sterling		144	21	133					
21 ³	T 7 Increase	F	53	41	12	39.25	13.25	3.03 : 0.97	0.16	1 : 1
22 ³	T 17 do	F	64	51	13	48	16	3.39 : 0.81	0.15	1 : 1.63
23 ³	T 21 do	F	83	58	25	62.25	20.75	2.88 : 1.12	0.13	1 : 1
23 ³	T 28 do	F	77	61	17	57.75	19.25	3.10 : 0.90	0.13	1 : 4
	Totals for 3 : 1 ratio		1445	1057	338	1046.25	348.75	3.03 : 0.97	0.03	1 : 1
	Totals for 1 : 1 ratio		196	100	96		98 98	1.02 : 0.98	0.05	1 : 1

¹ G = seed produced in the greenhouse, cheese cloth partitions. F = isolated field plots.² Commercial seed lot (Northrup, King and Co., "Sterling") as check.³ Increase plots; mixed population of resistant plants from a given selection. See Table No. 1.

variation in the resistant types, there was little approach to an intermediate condition (See figure 1).

Groups 1 to 16, inclusive, are each the progeny of clonal lines, which have been selfed in the greenhouse or in the field, according to the methods described. Where seed was obtained from a clonal line by growing vegetatively propagated plants in an isolated plot in the small grain nursery, and also from the same line by being self-fertilized within cheese cloth partitioned booths in the greenhouse, the results are not in general different. There is one exception, however, in group 4. The ratio of resistant to susceptible is more nearly 1:1 than 3:1, possibly indicating that this clone was not sufficiently isolated in the field and that the seed produced was almost completely the result of cross pollination with susceptible unselected plants—some escaped, or “wild” plants were evidently nearer this plot than was realized. All of the other “self-fertilized” clones conform about as closely to expected results as might be anticipated upon the basis of the numbers concerned in each case. The crosses, groups 17 and 18, fall well within the expectation.

Groups 20 to 25, inclusive, are from the increase plots as described in the foot-note 1 of table 1. Each of these increase plots consists of several resistant plants from the selection number indicated. Consequently, the seed produced is perhaps in part the result of self-fertilization and in part inter-fertilization of the resistant plants of this selection. It is interesting to note that the reaction of the seedlings of each of these groups approximate very closely a 3:1 ratio.

On the basis of the tests recorded in part in table 3, further selections for desirable types of timothy homozygous for rust resistance, and possessing as much self-fertility as possible, is being continued by the Minnesota Experiment Station.

SUMMARY

1. Preliminary breeding tests of various selections of timothy for rust resistance indicated that certain selections were quite resistant to rust. Some selections consisted almost entirely of resistant plants, others possessed few, or no resistant plants. The large number of resistant plants in certain selections suggested that resistance might be a Mendelian dominant.

2. On the basis of the field test, further selections were made. This included several clonal lines from which self-fertilized seed was obtained and certain crosses were made.

3. Various clonal lines were inoculated with collections of timothy rust from different localities in the United States and Canada. No definite

evidence of biologic specialization of *Puccinia graminis phleipratensis* was found, although more experiments should be made.

4. The fact that the resistant clonal lines of timothy were resistant to rust collected from widely separated localities lends encouragement to the production of rust-resistant varieties.

5. If no biologic forms of *P. graminis phleipratensis* exist, the fact may be of considerable significance in connection with the origin of biologic forms.

6. Inoculation experiments on seedlings produced from self-fertilized clonal lines, and from crosses between clonal lines, indicate that resistance or susceptibility in the selections of timothy studied is dependent upon a single differential factor pair. Resistance appears to be a dominant, and a close approximation to a 3:1 ratio was obtained in the progeny of self-fertilized resistant plants.

7. The facts presented in this paper indicate that the production of varieties of timothy, which will be resistant to stem rust in different regions, may be accomplished rather easily.

LITERATURE CITED

1. AAMODT, O. S. The inheritance of growth habit and resistance to stem rust in a cross between two varieties of common wheat. Jour. Agric. Res. 24: 457-469. 2 pl. 1923. Literature cited, p. 468-469.
2. BIFFIN, R. H. Studies in the inheritance of disease-resistance. Jour. Agric. Sci. 2: 109-128. 1907.
3. EVANS, I. B. P. South African cereal rusts, with observations on the problem of breeding for rust-resistant wheats. Jour. Agric. Sci. 4: 95-104. 1911-12. Bibliography, p. 104.
4. HAYES, H. K., and H. D. BARKER. The effects of self-fertilization in timothy. Jour. Amer. Soc. Agron. 14: 289-293. 1922. Literature cited, p. 293.
5. HAYES, H. K., J. H. PARKER and CARL KURTZWELL. Genetics of rust resistance in crosses of varieties of *Triticum vulgare* with varieties of *T. durum* and *T. diococcum*. Jour. Agric. Res. 19: 523-542. Pl. 97-102. 1920. Literature cited, p. 541-542.
6. HAYES, H. K., and E. C. STAKMAN. Rust resistance in timothy. Jour. Amer. Soc. Agron. 11: 67-70. 1919. Literature cited, p. 69-70.
7. STAKMAN, E. C., and LOUISE JENSEN. Infection experiments with timothy rust. Jour. Agric. Res. 5: 211-216. 1915. Literature cited, p. 216.
8. STAKMAN, E. C., and F. J. PIEMEISEL. Infection of timothy by *Puccinia graminis*. Jour. Agric. Res. 6: 813-816. 1916. Literature cited, p. 816.
9. STAKMAN, E. C., and F. J. PIEMEISEL. Biologic forms of *Puccinia graminis* on cereals and grasses. Jour. Agric. Res. 10: 429-495. Pl. 53-59. 1917.
10. STAKMAN, E. C., and F. J. PIEMEISEL. A new strain of *Puccinia graminis*. Phytopath. 5: 73. 1917.

11. STAKMAN, E. C., and M. N. LEVINE. The determination of biologic forms of *Puccinia graminis* on *Triticum* spp. Minnesota Agric. Exp. Sta. Tech. Bul. 8. 10 p., 1 fig. 1922. Literature cited, p. 10.
12. STAKMAN, E. C., M. N. LEVINE and D. L. BAILEY. Biologic forms of *Puccinia graminis* on varieties of *Avena* spp. Jour. Agric. Res. **24**: 1013-1018. 4 pl. 1923. Literature cited, p. 1017-1018.

WITCHES' BROOM OF POTATOES IN THE NORTHWEST

CHAS. W. HUNGERFORD AND B. F. DANA¹

WITH PLATE XXV AND FOUR FIGURES IN THE TEXT

INTRODUCTION

During the summer of 1923, an unusual disease of potatoes has been reported throughout the Pacific Northwest by various plant pathologists and others concerned with the certification of seed potatoes. The disease, which has been noted on all the commercial varieties grown in this section, is apparently very similar, if not identical with, the one figured and very briefly described by Bisby and Tolaas (1) as occurring in Minnesota. They have called the disease witches' broom and, as the name seems appropriate for the disease which we are describing, we have retained it.

The meager amount of information available concerning the trouble and its widespread occurrence the past season has made it seem desirable to prepare a preliminary note giving the results of observations made by the authors and others. The data given are largely observational. Experimental work to determine the nature of the disease and its possible relation to other diseases of the potato has been started. The data herein presented include not only observations made by the writers, but also notes relative to the occurrence of the trouble furnished by Prof. H. E. Morris of the Montana Agricultural Experiment Station, Mr. E. R. Bennett of the Idaho Agricultural Extension Division, and Mr. J. E. Currey of the Washington State Department of Agriculture.

The symptoms of the disease differ in many respects from those of any disease with which the authors are familiar. Indeed, the appearance of the diseased plants is so striking that growers have readily recognized it as a separate disease. However, as it has not yet been possible to complete careful experimental work and as the cause has not been determined, we do not claim that the disease may not be an unusual manifestation of some known trouble or an unusual combination of known troubles.

OCCURENCE AND DISTRIBUTION

Witches' broom has been given very limited attention by writers discussing potato diseases. Whipple (8) pictures a "yellow top degenerate" which is apparently identical with one phase of witches' broom. He further

¹ Published with the approval of the Directors of the Washington and Idaho Agricultural Experiment Stations as Scientific Paper No. 108, College of Agriculture and Experiment Station, Pullman, Washington, and Research Paper No. 27, College of Agriculture and Agricultural Experiment Station, Moscow, Idaho.

pictures and describes the progeny of such a hill which is similar to progeny of witches' broom plants developed by the writers. Tuber development described by Whipple for the "yellow top degenerate" is very characteristic of witches' broom and leaves little question but that the two diseases are identical.

Bisby and Tolaas (1) barely mention witches' broom of the potato as of rare occurrence in Minnesota and suggest that it may be similar to spindling sprout which is said to be rather uncommon with them. These writers picture this disease and also the spindling sprout, making it evident that the witches' broom they studied was the same as that occurring in the Northwest.

Cutler and Sanford (4) and Coons and Kotila (3) also consider witches' broom as associated with spindling sprout. Professor Cutler, in a letter dated January 24, 1924, states that witches' broom was not common in his district. Coons and Kotila do not consider the disease of commercial importance as it eliminates itself by reduction in size of tubers.

This same disease was observed by Dr. F. D. Heald in 1917 at Pullman, Washington, but at that time he did not differentiate between it and the effects of *Rhizoctonia* which was abundant on the undergrown parts of the affected plants. No special study of the disease was made and no further occurrences of the trouble in Washington were noted until the season of 1923.

These meager reports are sufficient to give basis for the belief that this disease has occurred occasionally in seed stocks and was considered a manifestation of "running out" or was confused with other diseases. Study has probably been limited because of the fact that diseased hills usually produce very few tubers and self-extinction of severely diseased stocks is sudden and complete under ordinary conditions.

During the summer of 1923 the disease occurred promiscuously throughout the Northwest in certified and non-certified seed stocks. Growers and inspection officials have been interested in the disease because of its distinctive symptoms. Excellent opportunity was offered for study by the appearance of the disease in experimental plots at the Washington and Idaho Experiment Stations. At both stations the disease has occurred in the field and greenhouse-grown selections used for the study of the leaf roll and mosaic diseases. The seed stocks used for these studies have been under observation for several years without any of the disease being observed.

SYMPTOMS OF WITCHES' BROOM

We have noted two types of symptoms which in the light of present data we suggest may be primary and secondary symptoms of witches' broom. The primary symptoms described are those appearing during the

growing season and evidently developing subsequent to the infection of a normal plant with the disease. Secondary symptoms, or those appearing in plants produced from diseased seed, differ considerably from the primary symptoms and will be described separately.

Due to the fact that the secondary symptoms were noted first, we have chosen to describe them before we take up the primary symptoms.



Fig. 1. Extreme witches' broom development on a Netted Gem potato plant.

Secondary Symptoms from Diseased Tubers

The characteristic bushy appearance of plants from infected seed has given rise to the name witches' broom. Typical diseased plants are shown in figure 1, and plate XXV, fig. 1. As will be noted, every eye on the seed tuber must have given rise to a stalk and these in turn produced side shoots at every available bud. One of the most constant symptoms of this disease in all stages is the tendency for all buds, including those usually latent on a normal plant, to push into growth.

The symptoms associated with the disease were studied in detail in diseased plants found in the experimental plots at both the Idaho and Washington Agricultural Experiment Stations, and in various commercial fields throughout the two states. Opportunity was also offered to study the oc-

currence of these symptoms in some volunteer potatoes on the Washington Experiment Station. Figure 1 is a photograph of a diseased volunteer plant. As may be noted in the figure, the nodes are somewhat enlarged. Leaf-petioles and stems are smooth and rounded having none of the angular conformation of a normal potato plant. Leaf-petioles tend to be elongated and the leaflets narrow and spaced some distance apart. The leaves, stems and flower clusters assume an upright position giving a very characteristic appearance to the plant. The production of flower clusters and the setting of seed balls is sometimes emphasized in such plants. The affected volunteer plants were of large size and nearly as dark green in color as normal plants. The plants withered and died earlier than other vounteer plants in the same field.



FIG. 2. Prolonged stolon development with formation of successive tubers on a Netted Gem potato plant.

The witches' broom plants developing in the experimental plots, although of the same variety, did not attain the size of the volunteer plants. The foliage was not so luxuriant and the color was distinctly yellowish. Plate XXV, fig. 5 shows plants of this character. They are similar to the plants pictured and described by Whipple (8) as "yellow top degenerates." The symptoms, otherwise, were similar to those described for the volunteer plants. All parts, however, were reduced in dimensions and the leaflets were somewhat crinkled in appearance. The tendency to bloom and set seed balls was

often pronounced in plants of this character. This type of plant was observed in certified and non-certified seed stocks in which the disease had not been recognized the previous season. Essentially the same symptoms were exhibited under irrigated as under dry-land conditions and in some fields were found in as high as twenty-five per cent of the plants. Plants of this type retained their upright habit of growth until the period of rapid decline which was long before the normal ripening period for the field.

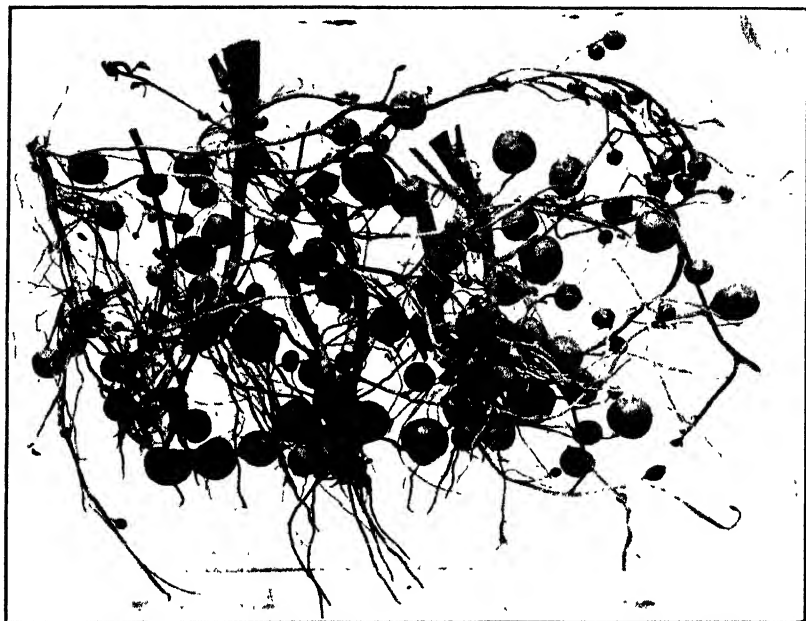


FIG. 3. Bliss Triumph potato showing excessive number of tubers produced on some diseased plants.

The outstanding features of plants of this character were the yellowish color, and the increased number of shoots making appropriate the term "witches' broom."

The production of aerial tubers took place on witches' broom plants of the Bliss Triumph variety in experimental plots at the Idaho Station and were also noted many times on this variety in commercial fields. Plate XXV, fig. 1 shows one of these plants with the leafy aerial tubers on the lower half of the stems. The other characters were similar to witches' broom described above.

Aside from the symptoms on the foliage, the tubers in diseased hills also present abnormalities which are very striking. One notices first, that

the number of potatoes in diseased hills usually very greatly outnumber those in healthy hills. As many as 200 tubers have been counted in a single diseased hill. Figure 3 illustrates this condition. As shown by the photograph, these tubers are usually very small, varying in size from about as large as a pea to the size of a walnut. Some of these tubers develop net



FIG. 4. Leafy tubers produced in the greenhouse on a Netted Gem potato plant.

necrosis similar to that found in leaf roll diseased stock, although this condition is not always present. One condition which is very characteristic of the disease wherever it has been noted is the fact that the various buds of all the eyes of the tubers have a tendency very early in their development to start growth. Aerial tubers on diseased plants quite uniformly produce leafy growths at the eyes. Tubers produced under ground have

been found with half a dozen stolons growing out of the eye end. These stolons often produced more tubers which sprout in turn forming a series of small tubers on the stolons in a manner resembling a chain of beads. See figure 2. Many of these elongated stolons later reach the surface of the ground and develop leafy-shoots coming up around the main plant thus covering the ground with a bushy growth several feet across. The appearance of such a plant is very striking. A farmer once remarked to one of the authors that these potatoes must have become crossed with quack grass. Nearly all of the witches' broom plants observed showed this development to some degree. In many cases the original plant died, but the growth of the surrounding shoots continued until killed by frost. Tubers produced by this type of plants were usually formed near the surface of the soil and were either leafy or produced short shoots at the normal position of the eyes. Such tubers did not mature by digging time and many shriveled in storage.

The production of stolons from tubers before the end of the season has been observed to follow conditions where a period of abundant moisture and lower temperature has followed a period of high temperatures and scarcity of moisture. In Eastern Washington and Northern Idaho such a condition prevailed in 1919. On the advent of moisture following the drought, the tubers produced stolons and shoots which pushed up through the soil. A similar condition has been described by Clinton (2) in Connecticut. It is felt by the writers that this condition is not related to witches' broom because seed stock from these fields produced normal plants the following year and the symptoms were by no means so extreme in any case as in the witches' broom development.

That witches' broom is transmitted by the tubers was conclusively shown in some tuber unit plantings made at Moscow, Idaho, in 1923. Plate XXV, fig. 5 shows three tuber units grown from some Bliss Triumph stock which was carefully rogued in 1922. The four hills in the lower righthand corner of the picture are from a diseased tuber, while those in the rear and to the left are healthy. Whipple (8) also calls attention to the fact that his "yellow top degenerate" always appeared in tuber unit groups.

The progeny of seriously diseased witches' broom plants, when grown in the greenhouse, often have a spindling sprout type of growth. One to several thin shoots develop from each bud on the tuber. Growth continues to be retarded throughout the development of the plant under greenhouse conditions. Small aerial tubers are common on such plants while practically no normal tuber production takes place. Figure 4 shows leaf character and aerial tuber production on greenhouse-grown progeny of witches' broom plants.

The spindling sprout figured by Stewart and Sirrine (7) and by Stakman and Tolass (6) does not appear like that described above because of growth taking place from only a few buds. Bisby and Tolaas (1), although showing the same cut of spindling sprout as Stakman and Tolaas (6), suggest that it may be related to witches' broom. Cutler and Sanford (4) and Coons and Kotila (3) in their considerations of spindling sprout and witches' broom, respectively, describe a large number of spindling sprouts arising from the seed piece. This is also characteristic of the spindling sprout related to witches' broom as worked with by the authors. Whipple (8) connected this type of spindling sprout with the "yellow top degenerate." The spindling sprout figured by McKay (5) is identical in habit with that studied by the writers.

With the exception of Bisby and Tolaas (1) and Coons and Kotila (3), the workers mentioned above have not noted relationship of spindling sprout to any other symptoms developing on the plants. From the preliminary work accomplished we believe that spindling sprout often accompanies extreme deterioration or degeneration from the witches' broom disease. We also recognize the fact that other types of spindling sprout may have entirely different causal relations.

Primary Symptoms Appearing Late in the Season

All of the symptoms described above have been those appearing early in the season from apparently diseased sets. Later in the season what is apparently the same disease appeared on plants previously showing none of these symptoms. In one plot of Bliss Triumph potatoes, grown at Moscow, Idaho, on the Experiment Station Farm, five per cent of the plants were rogued out early in the season on account of witches' broom. Soon after August first it was noted that a considerable number of plants which had previously apparently been healthy were developing symptoms of the trouble. The first indication was a tendency for the newer leaves at the tips of the branches to become slightly rolled, lighter green with a reddish yellow margin and with an upright habit of growth. In a short time these symptoms became more marked so that affected plants could be noted at a considerable distance. The tendency for proliferation, described above, developed also in these plants, expressing itself in numerous shoots developing in the axils of leaves at the tips of the branches and also in the sprouting of the eyes in the new tubers formed underground. When these hills were dug, there were one or two normal well developed tubers which had apparently been formed before the plant became affected. Also there were many small tubers in the beadlike formation described above, which had evidently been formed after the plant became diseased. Sixteen per cent of the plants in the plot mentioned above were rogued out during

the later part of the season. Table 1 gives in percentage the number of plants removed from each plot both before and after August first. Those rogued before August first were evidently from diseased sets, while those rogued after August first showed the primary symptoms described above.

TABLE 1.—*Percentage of witches' broom plants rogued from certain potato plots grown at Moscow, Idaho*

No. of plot	Variety	Per cent rogued before Aug. 1st	Per cent rogued after Aug. 1st
19	Bliss Triumph	5	16.0
20	Bliss Triumph	10	8.0
12	Idaho Rural	0	6.2
13	Idaho Rural	0	3.5
14	Idaho Rural	0	3.2
15	Idaho Rural	0	4.0

Although we have no experimental evidence that this secondary development was due to the same cause as the trouble which appeared earlier in the season, the symptoms were so nearly similar that we were led to believe this to be the case. It was noted that the condition which developed later in the season many times occurred in plants immediately adjacent to the missing hills which had been rogued out earlier in the season.

Plate XXV, figure 3, shows a plant with these early symptoms, showing particularly in the leaves at the tips of the shoots. The leaflets on the shoots were rolled and in the Green Mountain variety the edges of these leaves were light yellowish in color, but with the Bliss Triumph a reddish color developed on the edges of affected leaflets. This was also true of the Cobbler and became more pronounced toward the end of the season. Affected plants were about normal in size. A more advanced stage is shown in Plate XXV, figure 4. Lower leaves were normal in size and texture, but the effect on the top was becoming pronounced. In the Netted Gem such plants in the field were conspicuous because of their yellow color and upright habit and tendency to bloom and set seed balls.

The primary stage of the witches' broom of potato has not been described in the literature available to the writers. Symptoms similar to these have in the past been ascribed to the attacks of the *Rhizoctonia* fungus, and may also easily be confused with the primary symptoms of leaf roll. In fact it may in some cases require the actual study of progeny to determine the difference between the primary stage of leaf-roll and witches' broom. The effect upon tuber formation seems to be a characteristic of the witches' broom disease only.

Nature of Witches' Broom

Sufficient data has not been gathered upon which to base a positive statement as to the cause of witches' broom. For the present we can only describe the conditions under which the disease has appeared. These data may indicate the factors responsible for or influencing the disease and from which a theory as to the cause of the disease may be formulated. Such a theory will be useful in correlating further data and in giving direction to such experimental work as is necessary to furnish proof of the cause of the disease.

During the past season witches' broom has occurred under a wide variety of conditions. It was manifest in considerable amounts in the fertile Skagit River Valley of western Washington. No more ideal conditions could be desired for the growing of potatoes than were to be found in this valley. The disease was likewise observed under very favorable growing conditions in the Willamette River Valley of western Oregon, and in the Snake River Valley of southern Idaho. The appearance of the disease under such favorable conditions would tend to show that lack of moisture or plant food were not responsible for its appearance or severity. On the other hand, the disease was observed in northern Idaho and in eastern Washington, under very adverse conditions as well as under moderately favorable conditions for potato culture. Some very severe cases occurred on thin soil where there was a positive shortage of moisture. Under such conditions the plants succumbed early, but the symptoms were essentially the same as those occurring on plants in good soil and well supplied with moisture.

Diseased Netted Gem stock divided and planted under irrigation in central Washington and under dry land culture in eastern Washington produced plants having similar symptoms. In connection with a study of potato mosaic and leaf roll being carried on at the Idaho Experiment Station, the effect of environmental conditions upon the development of these diseases is being tested by planting the same lots of seed in various localities. In 1923 a certain lot of Bliss Triumph seed was divided and grown at Moscow, Coeur d'Alene, and Winchester under non-irrigated conditions, and at Ashton and Parma under irrigation. Witches' broom developed at all of these places. The amount of infection early in the season was practically the same at all five places. Our data seem extensive enough to warrant the conclusion that environmental factors during the growing season do not control the appearance of witches' broom.

The disease was noted in fields planted both early and late, and it was also observed in a field of volunteer potatoes. Periodic plantings were made every two weeks from April to July, at Pullman and Prosser, Washington, of stock which developed about three per cent of the disease; no appre-

cial relation was noted in these plots between time of planting and the development of the disease. From a study of the disease throughout the season we may say that seasonal variation does not seem to greatly influence the percentage of disease appearing in seed stocks but may influence the size and longevity of the affected plant.

The question naturally arises whether improper storage conditions may not be a possible factor in the production of witches' broom. Evidence at hand does not warrant such a conclusion. Reference has already been made to the occurrence of the disease in a field of volunteer potatoes. The disease has also been observed in many different unrelated stocks kept in common storage for the winter. Specially selected stock at both the Idaho and Washington Experiment Stations kept in good commercial storage during the winter showed an appreciable amount of the disease in the resultant crops. Over the region where this disease has appeared there must of necessity have been a wide variation in the storage conditions under which the various stocks were kept. The appearance of the disease under such a variety of conditions would tend to show that storage conditions do not cause the disease. This point is strengthened by the occurrence of the disease in selections planted in the greenhouse after only a short rest period following the harvest.

The transmission of witches' broom has not been accomplished under controlled conditions. Enough evidence has accumulated, we believe, to prove that the disease is carried by tubers. The same seed stock planted at the same time in widely separated places and otherwise handled the same has shown the disease in practically the same percentage and severity. The same hill selections planted in the greenhouse and portions also planted in the field show like infections of the disease. Progeny of witches' broom selected from the field have shown typical symptoms when grown in the greenhouse.

The dissemination of witches' broom in the field was indicated on the Idaho Station by the results secured in the test plots mentioned above. Here there seemed to be evidence that infection took place during the growing season. The appearance of the disease in partly grown plants which develop typical symptoms in those portions developing thereafter would indicate that the disease is spread during the growing season. Investigational work is in progress which it is hoped will show how the disease is spread and also furnish a basis for conclusions as to the cause of the malady.

The witches' broom disease has some symptoms in common with several other disease, among which may be mentioned *Rhizoctonia*, leaf roll, and spindle tuber. The *Rhizoctonia* fungus has not been constantly associated with the disease and furthermore, it has been shown that witches' broom is



Fig. 1. Witches' broom with production of aerial tubers on Bliss Triumph plant. Fig. 2. Leafy shoots developing from elongated stolons on Netted Gem plant. Fig. 3. Symptoms of recent infection on Green Mountain plant. (Photograph by J. E. Currey.) Fig. 4. Well developed symptoms on the top of Netted Gem plant. Fig. 5. Three tuber units of Bliss Triumph variety, one of which is affected with witches' broom.

constantly transmitted by seed tubers. The symptoms common to witches' broom and leaf-roll are: the slight rolling of the upper leaves on newly infected plants, the spindle sprout symptoms, and the net necrosis sometimes developing in the tubers. Aside from the fact that the type of leaf roll and the spindle sprout described above for witches' broom are radically different from the same manifestations of the leaf-roll disease, the other symptoms which we have discussed have not, to the knowledge of the writers, been associated with leaf roll. The above statement will also apply in a comparison of witches' broom and the spindle tuber disease. The symptoms characterizing witches' broom have not yet been mentioned in descriptions of the spindle tuber disease available to the writers.

In view of the facts set forth in this paper, we believe that we are justified in considering witches' broom a distinct disease of the potato. The cause of this disease, which was widely distributed during 1923 throughout the Pacific Northwest, has not been found. Work is progressing along several lines and it is hoped that more concerning the nature and cause can be given in a later paper.

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AGRICULTURAL EXPERIMENT STATIONS,

PULLMAN, WASHINGTON AND MOSCOW, IDAHO.

LITERATURE CITED

1. BISBY, G. R., and A. G. TOLAAS. Potato diseases in Minnesota. Minnesota Agric. Exp. Sta. Bul. 190. 41 p., 28 fig. 1920. References, p. 44.
2. CLINTON, G. P. New or unusual plant injuries and diseases found in Connecticut, 1916-1919. Connecticut Agric. Exp. Sta. Bul. 222: 395-482. Pl. 33-56. 1920.
3. COONS, G. H., and J. E. KOTILA. Michigan potato diseases. Michigan Agric. Exp. Sta. Bul. 125. 55 p., 49 fig. 1923.
4. CUTLER, G. H., and G. B. SANFORD. Potato diseases. Univ. Alberta, Coll. Agric., Dept. Extens., Field Husbandry Circ. 7. 23 p., 14 fig. 1921.
5. MCKAY, M. B. Potato diseases in Oregon and their control. Oregon Agric. Exp. Sta. Circ. 24. 53 p., 37 fig. 1922.
6. STAKMAN, E. C., and A. G. TOLAAS. Potato diseases and their control. Minnesota Agric. Exp. Sta. Bul. 158. 47 p., 28 fig. 1916.
7. STEWART, F. C., and F. A. SIERKINE. The spindling sprout disease of potatoes. New York (Geneva) Agric. Exp. Sta. Bul. 399: 133-143. 3 pl. 1915.
8. WHIPPLE, O. B. Degeneration in potatoes. Montana Agric. Exp. Sta. Bul. 130. 29 p., 16 fig. 1919.

EQUIPMENT AND METHODS FOR STUDYING THE RELATION OF SOIL TEMPERATURE TO DISEASES IN PLANTS.

R. W. LEUKEL

WITH FIVE FIGURES IN THE TEXT

INTRODUCTION

Soil temperature is receiving increasing recognition as an important factor influencing the development of plant diseases especially soil-borne and seed-borne diseases and those attacking the underground parts of plants.

The study of soil temperature up to 1921 has been admirably summarized by Jones¹ and a brief description given of the Wisconsin tank now used in the Department of Plant Pathology at the University of Wisconsin and in a number of other institutions in this country.

The writer fortunately had the opportunity of using this apparatus from 1920 to 1922 in connection with certain cereal-disease studies conducted cooperatively by the Office of Cereal Investigations, Bureau of Plant Industry, and the University of Wisconsin. In 1922 the writer was transferred to Washington, D. C., where equipment for the control of soil temperature was installed in the cereal-disease greenhouse at Arlington Experiment Farm.² In the installation several difficulties were encountered. The supply of water at Arlington Experiment Farm is limited and its temperature comparatively high so that special means for obtaining low soil temperatures had to be devised. High pressure steam is not constantly available and when needed had to be supplied from a small boiler in the greenhouse basement. All electrical equipment had to be adapted to a 220-volt 25-cycle alternating current.

In this paper is presented a detailed description of the various items of equipment together with their operation and the methods employed at Arlington Experiment Farm in the study of the relation of soil temperature to certain cereal diseases. It is thought that this may be of interest to those contemplating the installation and operation of similar equipment.

The actual results of the experiments will appear in a later series of papers.

¹ Jones, L. R. Experimental work on the relation of soil temperature to disease in plants. *Trans. Wis. Acad. Sci., Arts and Letters* 20: 433-459, *pl. 33-37*. 1921.

² Much of this work was done under the general direction of Dr. A. G. Johnson whose helpful advice and suggestions are gratefully acknowledged.

THE TEMPERATURE-CONTROL TANK AND ITS EQUIPMENT

The Tank

The tank (Fig. 1), which is copied after the one devised at the Department of Plant Pathology of the University of Wisconsin, is a rectangular structure 21 inches wide, 39 inches long, and 28 inches deep on the inside. The lining is of 24-gauge galvanized iron. The upper three inches of metal are turned out at right angles to the sides to lap over the upper edges of the outer wooden wall. All seams are well soldered and made water tight.

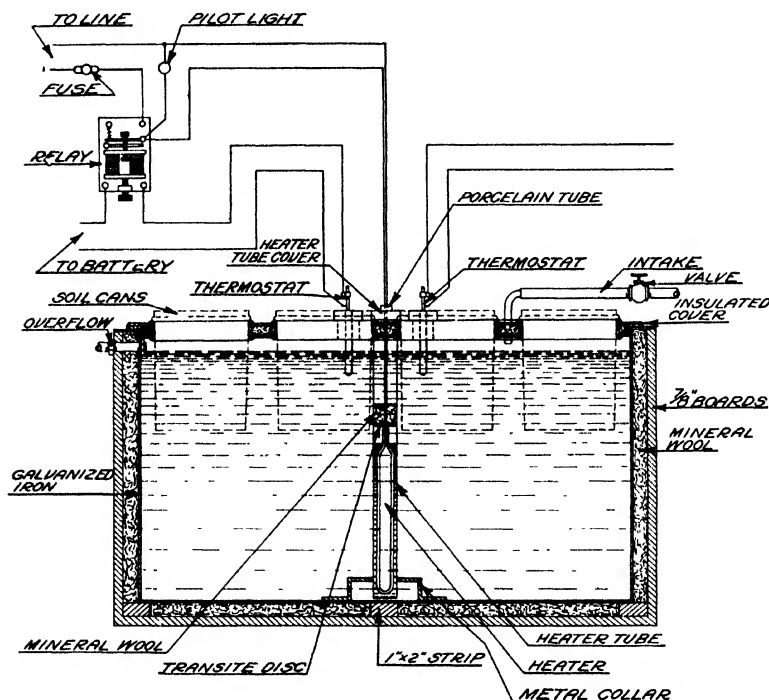


FIG. 1. Soil temperature-control tank and part of its accessory equipment for maintaining constant high, low or medium soil temperatures. The thermostat on the right regulates the inflow of cold water and the one on the left controls the heater.

The outer wall is made of seven-eighths-inch cypress boards nailed to 2" x 4" material at the corners. The inside dimensions of this outer wooden unit are about 3 inches greater than those of the metal lining. The space between the wood and the metal is packed with mineral wool. A half-inch overflow pipe near the top of one end is held in place by

lock nuts, and leads to a return pipe through which the water flows back to the ice-water tank, as described later.

The Cover

The cover (Fig. 2) consists of a top and bottom of galvanized iron with a solid piece of half-inch "flax linum" between. The lower sheet of metal is bent over the edges of the insulation and joined to the upper sheet of metal to form a flange which rests on the metal edges of the tank.

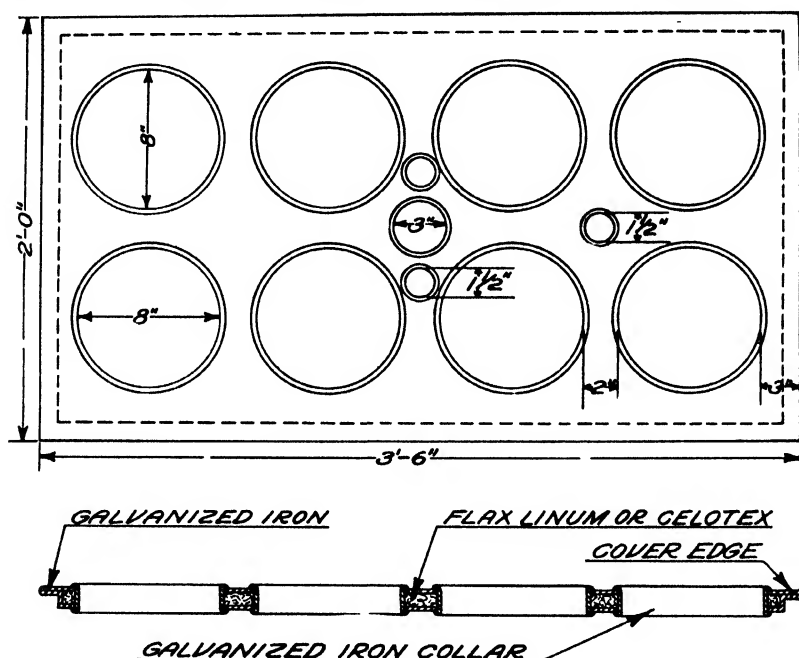


FIG. 2. Diagram of the cover for the soil temperature-control tank showing the arrangement of the openings. The cross section shows its construction.

The 8-inch openings for soil cans are placed about three inches from the edge. The three-inch opening in the center is for the heater tube. On each side of this 3-inch opening is a 1 1/2-inch opening, one for the thermostat and the other for the thermometer. In the middle of one end of the cover is another 1 1/2-inch opening for the cold-water tube. The openings are lined with galvanized iron collars, fitted around the inside edges and soldered water-tight.

All metal on the tank and cover is given three coats of water-proof paint. The cost of a completed tank and cover is approximately thirty dollars.

Cans

The soil cans (Fig. 3A) are suspended in the openings of the covers described above. They are made of 24-gauge galvanized iron with seams well soldered so as to be water-tight. They are $9\frac{1}{2}$ inches deep, 8 inches in diameter at the top, and slightly less than 8 inches at the bottom so that

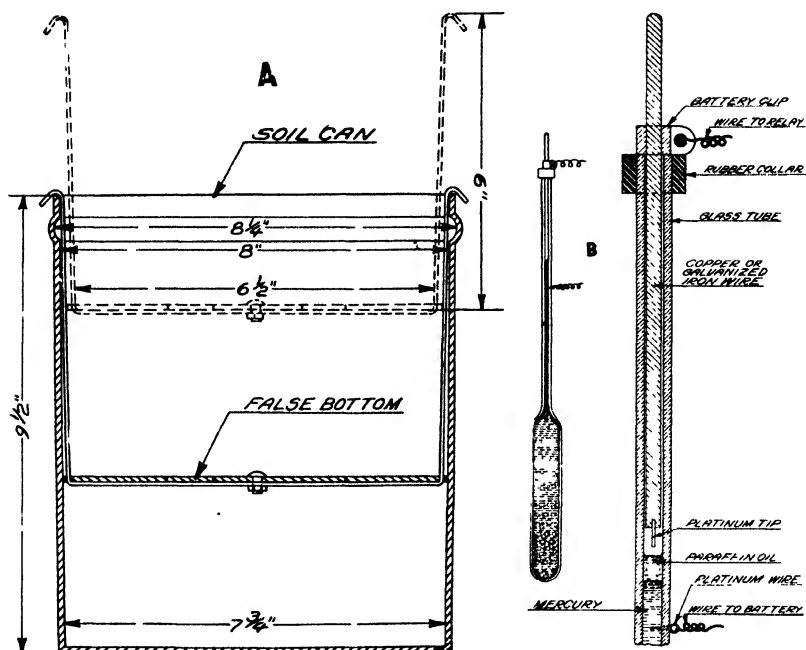


FIG. 3. A. Diagram showing the dimensions and structure of the soil cans together with the device used for transferring seedlings to a greenhouse bench. B. Thermostat used for regulating temperatures in the soil temperature-control tanks.

they can be removed easily for daily weighing and watering. The cans are beaded one inch from the top to support them in the openings. They can be made for about seventy-five cents each.

Heater Tube

A vertical heater tube, illustrated in figure 1, has been adopted in the temperature-control tanks at Arlington Experiment Farm instead of the troublesome "gooseneck" type of heater tube, commonly used in the Wisconsin tanks. This vertical heater tube is 3 inches in diameter and extends from the bottom of the tank to 2 inches above the cover. A metal collar soldered about the tube just below the tank cover prevents it from slipping

up through the opening and also serves as a support for the center of the cover. The bottom of the tube is held in place by a metal collar soldered to the bottom of the tank. A 250-watt luminous radiator bulb, or other heater, is placed in the bottom of the tube and immersed in kerosene, which serves to conduct the heat away from the heater. The wires from the heater pass through a close-fitting transite disc and then through several inches of well packed mineral wool. This prevents the kerosene from vaporizing and keeps the heat from rising to the top of the tube. A metal cover fits closely over the heater tube and the wires pass through a short porcelain tube fitted into a hole in the center.

Heaters

Of the various types of heaters tried up to the present time, the Westinghouse 250-watt luminous radiator bulbs have been found most satisfactory. Other types, especially the General Electric cartridge unit, under certain conditions, have given good service. Although rather fragile, the luminous radiator bulb is convenient to use in connection with the heater tube described and in trials conducted by the writer with an ordinary watt-hour meter it was found to be relatively economical in current consumption in maintaining the higher temperatures. The cost of the Westinghouse radiator bulbs is \$2.50 each. An ordinary carbon light bulb is suitable for maintaining medium temperatures providing the air temperature does not vary too much.

Relays

A relay connected in series with a battery and with a simple mercury thermostat immersed in the water of the temperature-control tank is used to control the heating current (Fig. 1). At the lower temperatures relays are used also to control the motors operating the cold-water pumps (Fig. 4).

If a direct electric current is not available and a battery must be used to operate the relays, it is desirable to secure a relay which operates on a very small amperage. A 250-ohm telegraphic relay is satisfactory. When operated by a 6-volt battery, 18 such relays draw less than $\frac{1}{2}$ ampere. These relays cost about seven dollars each.

Where direct electric current is available a battery is not needed and a cheaper relay will suffice. The direct current can be reduced to the desired amperage by inserting resistance in the line and a 50-ohm pony relay, costing about three dollars, will then answer the purpose.

The relays should be examined and adjusted, occasionally as the hinge screws often work loose and throw the contact points out of alignment. The contact points should be kept clean, and if they fuse due to too heavy

a current passing through them they should be replaced by tungsten or molybdenum points.

Battery

As stated above, a direct electric light current reduced to the proper amperage by inserting resistance in the line is more satisfactory for operating relays than is a battery current, as the former is more constant and dependable. However, if only alternating current is available a battery must be used unless special relays are employed.

An ordinary sulfuric acid, lead-plate storage battery of 6 volts and of 110 ampere-hours capacity has been found satisfactory. This operates eighteen 250-ohm relays for more than a month before recharging is necessary. It is well to have another battery available for use while recharging the storage battery. A rectifier may be employed for recharging if no other means is available.

Thermostat

The thermostat employed (Fig. 3-B) was originally devised in the Department of Plant Pathology of the University of Wisconsin. It consists of a mercury bulb about $4\frac{1}{2}$ inches long and $\frac{3}{4}$ inches in diameter. It has a neck about $6\frac{1}{2}$ inches long with a bore of about $\frac{1}{8}$ inch or less. Three inches above the junction of the bulb and the neck a piece of No. 26 platinum wire, about $\frac{1}{2}$ inch long, is sealed into the glass tube with one end projecting into the bore to contact with the mercury and the other outside to attach to a wire leading to the relay. A close-fitting platinum-tipped wire plunger is inserted in the upper end of the neck and there held in any given position by a battery clip to which is attached a wire leading to the battery. The circuit is completed by a wire from the battery to the relay.

To adjust the thermostat for any given temperature it is immersed in water at that temperature until the mercury has acquired the temperature of the water. The platinum-tipped wire plunger is then adjusted so that it barely touches the mercury column.

The top of the mercury column may be covered with a thin layer of high grade paraffin oil to prevent it from oxidizing.

When the heater has brought the water in the tank to the desired temperature the mercury column in the neck of the thermostat makes contact with the platinum-tipped wire. This closes the circuit through the thermostat, the battery, and the relay coils and breaks the heating current by separating the contact points of the relay. When the temperature of the water has dropped sufficiently to separate the thermostat contacts, the battery circuit is broken and the contact points of the relay come together,

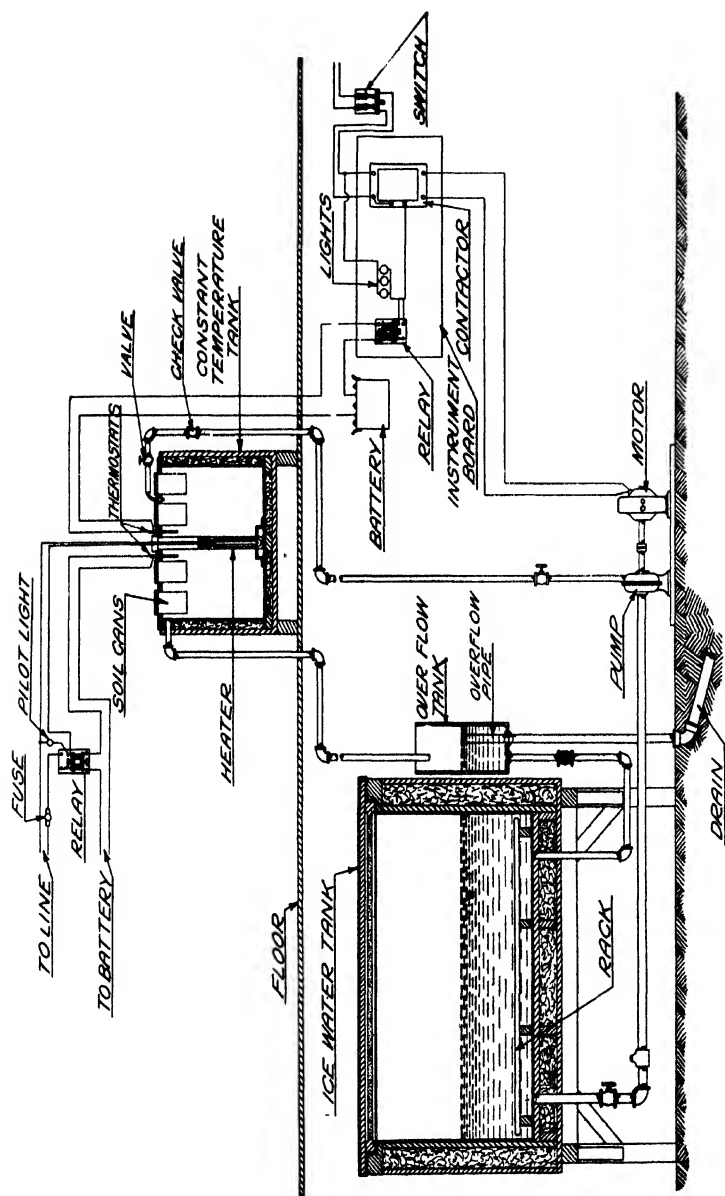


FIG. 4. Diagrammatic view of the soil-temperature-control equipment at Arlington Experiment Farm. The ice-water tank, pump, motor, etc., are in the basement below the temperature-control tanks, but if need be they may be on the ground floor, if so arranged that the top of the overflow tank is below the level of the water in the soil-temperature-control tanks. Only one pump, motor and contactor are represented here although several are used. At the higher and lower temperatures only one thermostat in each tank is necessary, but at temperatures between 13° C. and 20° C. two thermostats are advisable, one for heater control and the other for regulating the inflow of cold water.

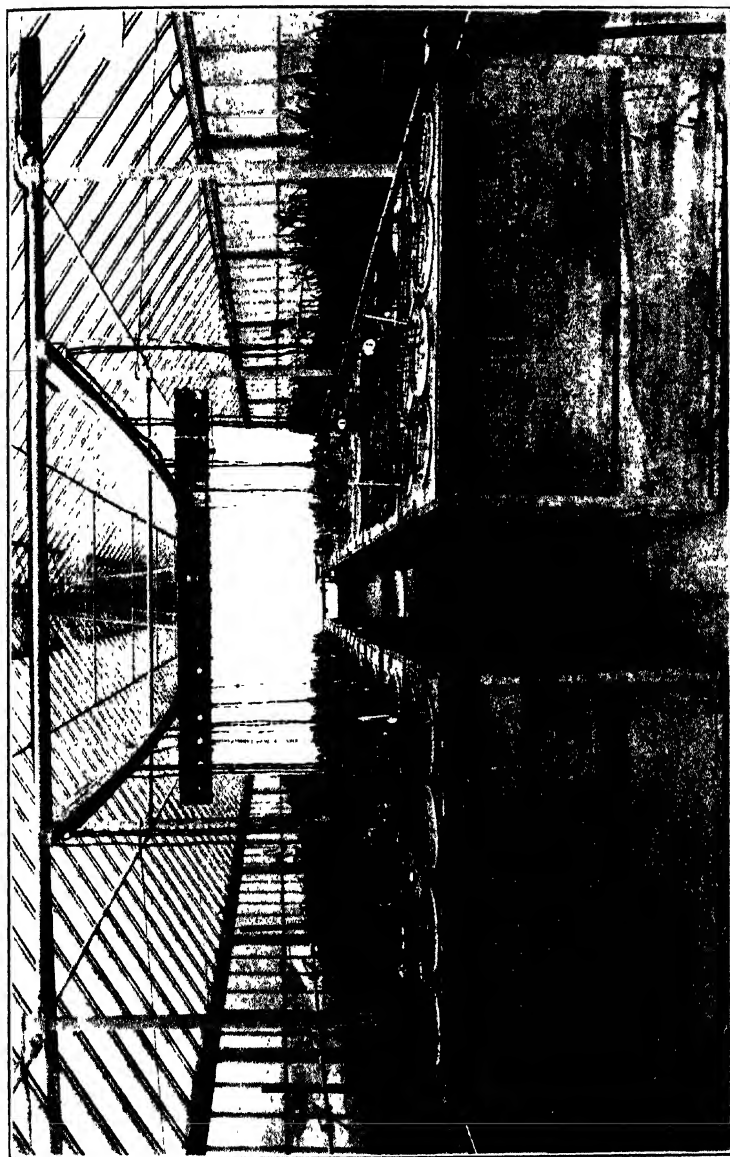


FIG. 5. General view of the soil-temperature-control tanks in the cereal disease greenhouse, Arlington Experiment Farm. On the switchboard is a relay, fuse and pilot light for each heater. Each relay is numbered to correspond to the number on the tank, the heater of which it operates.

closing the circuit through the heater and also through the pilot light on the switchboard. Although this thermostat is not entirely satisfactory, it is inexpensive, easily made, readily adjusted and sufficiently sensitive to keep the water within a half degree of the desired temperature.

Switchboards

The relays used to control the heaters are mounted on a switchboard (Fig. 1). For every heater in a temperature-control tank there is a corresponding relay, fuse and pilot-light on the switchboard. Each pilot-light indicates whether or not the corresponding heater is in operation. The wiring for this installation is shown in Fig. 1 and 5.

Another switchboard contains a fuse, relay, bank of lights and magnetic contactor for each cold-water pump. This installation is described above and illustrated in Fig. 4.

Low Temperature Equipment

Constant low temperatures in a number of the tanks are maintained by the thermostatically controlled flow of ice-cooled water into them whenever their temperatures rise above the desired points. This is accomplished by the apparatus shown in Fig. 4. The inside dimensions of the ice-water tank are 3 feet by 6 feet by 4½ feet deep. The details of its construction are shown in Fig. 5. Ice is placed on the rack in the ice-water tank. Water enters from the overflow tank and after being cooled is drawn out by a pump driven by a thermostatically controlled motor. The cold water is pumped to the temperature-control tanks,³ and enters each tank through a tube attached to a valved connection in the cold water line. These valves are adjusted so that the water flows at a rate necessary to obtain temperatures slightly below those desired. The rates of flow for different tanks held at the same temperature are about equal. The water is returned to the overflow tank from which it flows back into the large tank to be re-cooled and re-circulated.

The height of the water in the overflow tank and in the ice-water tank is governed by the height of the adjustable overflow pipe. In warm weather or when more tanks are to be cooled the water level is raised. In cold weather or whenever fewer tanks are in operation the water level is lowered, thus using less ice.

A wire screen over the outlet in the ice-water tank and a strainer in the pipe line prevent dirt from getting into the pumps. A valve below the

³ In this case the ice-water tank pumps, etc., are in a basement below the greenhouse. However, this part of the equipment can be located on the ground floor providing the level of the water in the temperature-control tanks is higher than the top of the overflow tank so that the water will return to the latter by gravity.

ice-water tank and another above each pump make it possible to shut off the water when necessary. Check valves prevent the water in the temperature-control tanks from siphoning back when the pumps stop.

An air temperature as near 15° C. as possible is maintained in the greenhouse where the temperature-control tanks are located. However, on cold winter nights the greenhouse temperature occasionally goes as low as 10° C. Therefore thermostatically controlled heaters are necessary in the tanks which are kept at 15° C. In warmer weather the greenhouse temperature often rises above 20° C. so that it is necessary to use cold water to prevent the temperature of the 20° tanks from going too high. This may be done by means of a thermostatically-controlled pump as in the case of the lower temperature tanks. A thermostat suspended in the water of one tank controls the flow of cold water into all of the tanks at that same temperature. When the temperature of the water rises above the desired point, the mercury column in the neck of the thermostat rises and makes contact with the platinum-pointed wire plunger. This closes the circuit through the battery and the relay coils. The relay-contact points are so arranged that the power circuit is closed whenever the battery circuit is closed. Therefore, the motor operates the pump until enough cold water has been added to the tanks to lower the water temperature to the desired point.

The $\frac{1}{2}$ and $\frac{3}{4}$ horse-power motors used to operate the pumps draw more current than can be passed through the contact points of the relays without causing them to fuse. Therefore, a magnetic contactor is used in connection with each relay. The installation of this is shown in Fig. 4. The leads from the main line are attached to the two upper posts of the contactor. Two wires from the lower posts lead to the motor. A bank of two or three 50-watt carbon filament bulbs in series with the relay and the armature of the contactor is connected in parallel with the contactor itself. When the battery current actuates the relay coils, the electric light circuit is closed through the bank of lights, the relay points, and the contactor armature, thus causing the contactor to close the circuit to the motor.

This apparatus kept the water in six of the temperature-control tanks at 8° C. for six months without much trouble, and at 4° C. for a shorter period. Another pump similarly controlled was used for the 15° tanks. In warm weather enough water was allowed to trickle into the 20° tank from the water line leading to the 10° tanks to keep their temperature from rising above 20° while the heaters kept them from being cooled below 20°. About six tons of ice were used each month.

EXPERIMENTAL METHODS

Type of Soil Used

One of the difficulties experienced in carrying on soil-temperature studies is encountered in the tendency of the soil to bake at the higher temperatures. This was overcome by using a soil containing a high percentage of organic material. A supply of well-decayed leaf mold was secured and sifted through a 4-mesh sieve. This material was mixed with an equal quantity of light clay loam, also sifted through a 4-mesh sieve. The water-holding capacity of this mixture was 72%, and at no time did it show any tendency to bake.

Soil Moisture

Soil temperature being the variable factor, it is necessary, of course, to keep the soil moisture uniform at the different temperatures. After screening and thoroughly mixing enough soil to fill all the cans used in a series, the moisture-holding capacity and the moisture content of the soil are determined. The soil is then spread out and sufficient water added with a sprinkler to obtain the desired moisture content. It is allowed to lie covered long enough for the water to permeate the soil so that the latter can be thoroughly mixed without puddling. When properly mixed, a uniform, weighed amount of soil is placed in each can. When the cans are suspended in the tanks, the surface of the soil should be slightly below the water line. Evaporation from the soil is reduced by placing a $\frac{1}{2}$ -inch layer of ground cork on the surface after the seeds have been sown. The cans at the higher temperatures are weighed daily and those at the lower temperatures less frequently. Any water lost through evaporation or by transpiration is replaced. At the higher temperatures, the water is applied around the edges of the cans, as that is where most of the drying occurs. The water used is of the same temperature as the soil. It may be taken from the tanks, or, if steam is available, tap water may be heated to the proper temperature. The watering device used is a cylindrical bucket six inches in diameter and about 12 inches deep. Near the bottom is an opening with an attachment for a quarter-inch rubber tube. This bucket is suspended overhead, and by means of the rubber tube a stream of water can be directed against the inside of the can, thus applying the water around the edge where it is needed most. The tube is provided with a pinchcock with which to shut off the water.

The scale used for weighing the cans is of the platform type commonly used in greenhouse experiments. It is sensitive to one gram and has a maximum capacity of 20 kilograms.

TEMPERATURE ADJUSTMENT AND MAINTENANCE

The water in the tanks is brought to the desired temperatures by the use of steam a day or two before any seeding is done so that the soil will have acquired the proper temperature by that time. A standardized thermometer is suspended in the water in each tank so that the bulb is three inches below the surface. Another thermometer is placed in the soil in one of the cans in each tank so that the bulb is at the seed level and one and a half inches from the side of the can. Temperature readings are taken three times daily. A typical day's reading (Table 1) shows the relation between the greenhouse air temperature, the water temperature, and the soil temperature. The temperature of the soil depends not only on that of the water but also to some extent on the air temperature and the intensity of the solar radiation.

The layer of ground cork on the surface of the soil helps to regulate the soil temperature by reducing radiation at the higher temperatures, and by shutting out the heat of the sun, to some extent. When the sun's heat becomes intense, partial shading with cheesecloth or thin muslin is advisable. Care should be taken, however, not to make the shading too heavy or too prolonged as the metabolism of the plants is affected by pronounced reduction in light intensity.⁴ Even with a constant water temperature it is difficult to maintain constant soil temperatures if the range in air temperature is excessive.

Seeding

Uniformity in depth and in other details of seeding is important. Cereal seeds are sown usually at a depth of one and a half inches. This depth is secured by removing a measured amount of soil from the can. The seeds are placed in a circle equidistant from the center and $1\frac{1}{2}$ inches from the side of the can. This is advisable because the temperature varies slightly at different distances from the side of the can. A cardboard disc five inches in diameter is helpful in placing the seeds the proper distance from the center and from each other. After tamping the seeds gently to hold them in place, the $1\frac{1}{2}$ inches of soil are replaced, a layer of ground cork added, and the can properly labeled and covered with heavy paper until emergence begins. The paper is then removed.

Transplanting

As infection by many of the cereal diseases such as bunt, for example, occurs only during the seedling stage of the plant, it is not always neces-

⁴ Garner, W. W., and Allard, H. A. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agr. Research, 18: 553-606, 1920.

sary to grow the plants at the different temperatures beyond the stage of fifth, fourth, or even the first leaf. They may then be transferred to the greenhouse bench or even transplanted to the field if weather conditions permit, and the cans and tanks made available for another series. The simple device used by the writer for transferring plants from the cans to the greenhouse benches is shown in Fig. 3. It consists of a perforated galvanized iron disc $6\frac{1}{2}$ inches in diameter suspended in the cans by means of two heavy galvanized iron wires hooked at the upper ends over the edge of the can. When the plants are ready for transplanting, the soil is first generously watered. It is then easily lifted out of the cans by means of the heavy upright wires and may be transferred to the bench where other soil is packed about it. Here the plants are grown to maturity or to a stage at which final notes on them may be taken.

OFFICE OF CEREAL INVESTIGATIONS,

BUREAU OF PLANT INDUSTRY,

UNITED STATES DEPARTMENT OF AGRICULTURE.

PERMANENT SPIRALS FOR TAGS

DEAN A. PACK

In connection with the work at this station, on the breeding of sugar beets, the author has devised an attachment for fastening identification tags to beets. This attachment consists of a galvanized spiral permanently fastened, by one end, to a metal tag carrying the identification number. Tags and spirals are illustrated in figure 1.

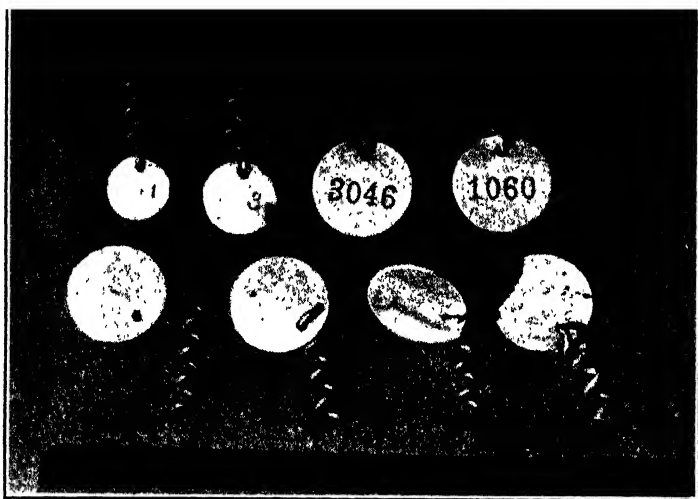


FIG. 1. Various sized tags and the attachment of the spiral to a tag.

These spiral tags may be used for various types of breeding, physiological, pathological, and field work, where plants or parts of plants are to be identified. The spiral tag is very desirable for some types of experimental work, because it has a constant weight due to being constructed entirely of metals. The tags are fastened to the plant by turning the spiral to the right into its tissues, and are removed by turning the spiral to the left. Some uses of these tags are indicated in figure 2.

The tags may be of various sizes and stamped from, either aluminum or brass. The spirals are made by winding number fifteen galvanized wire about a second wire $\frac{3}{16}$ of an inch in diameter. Ten feet of number fifteen wire will make from 145 to 150 turns, and produce a coil about ten inches long. This coil is then stretched to form a spiral about four and one half feet long. It is then cut into the proper tag spirals, having four turns each.



FIG. 2. Tags attached and in use.

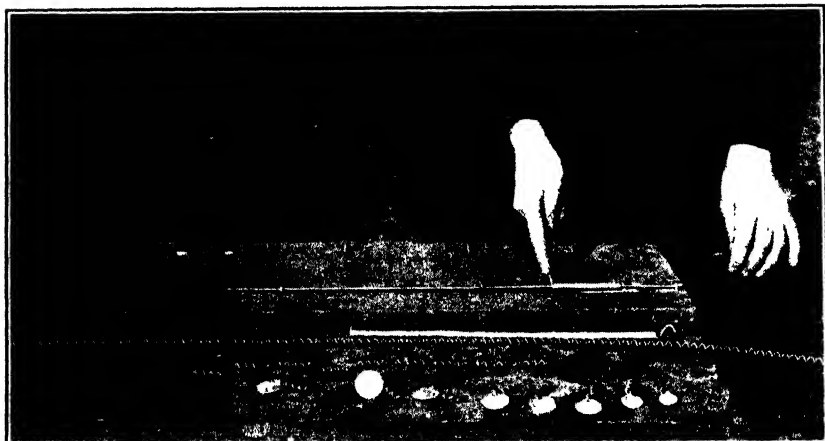


FIG. 3. The construction of spirals.

One turn is used for fastening the spiral to the tag, and the other three turns fastens securely the spiral in the beet. The size of the wire used in making these spirals, and the diameter of them, will depend upon the type of tissue one may be working with. The various steps in the construction

of these spirals and their attachments to the tags, are represented in figs. 1 and 3.

To a large extent, the value of a tagging method depends upon the degree of certainty one can place upon the method. There is no hesitation in the use of these permanent spiral tags. The spirals and tags are made of metals that do not readily corrode. The numbers being stamped into the metal tags are easily read and never become rubbed off. Each tag is permanently attached to its spiral, and should never be taken off. There is little danger of a tag becoming detached from a plant, because of the structure of the spiral. It requires a straight pull of from 48 to 79 pounds to draw one of these spirals out of an ordinary beet. This force is about ten times that required to draw the nails of a wooden label or tag out of a beet.

These spiral tags have been used during the past three years at this station with a great savings of time, money and labor.

PHYTOPATHOLOGICAL NOTES

Third Pan-American Scientific Congress. The Second Pan-American Scientific Congress was held in Washington from December 27, 1915, to January 8, 1916, and at that time the city of Lima in Peru was designated as the seat of the Third Congress. The sessions will commence November 16 and will last over the fortnight following. All branches of science will be represented in nine sections. Plant pathology falls under the Section of Biology, Agriculture and Related Sciences of which Dr. Wenceslao F. Molina is president. Mr. M. V. Villaran is president of the Congress and Mr. Jose J. Bravo, Secretary General, address, Apartado 889, Lima, Peru. The Organization Committee is inviting some of the more notable of American scientists to contribute papers and if possible to attend the Congress. If any of the members of the American Phytopathological Society have papers that they would like to contribute, or if they find that they can attend the Congress, it is suggested that they communicate with the secretary of their Society.

Horticulturists, entomologists and pathologists to meet in British Columbia. The Northwest Association of Horticulturists, Entomologists and Plant Pathologists will hold their seventh annual meeting at Pentteton, British Columbia, August 26 to 29, 1924. The membership of this association includes those interested in the three sciences in the states of Oregon, Washington, Idaho, Utah, and Montana and in the province of British Columbia. The Pacific Division of the American Phytopathological Society will also hold their annual meeting at the same time and place. This will be one of the most important scientific meetings ever held in the Pacific Northwest. Further information regarding these meetings can be secured by addressing either Prof. W. T. Hunter, Secretary of the Northwestern Association of Horticulturists, Entomologists, and Plant Pathologists, care of the Experimental Farms, Summerland, B. C., or Prof. Chas. W. Hungerford, Secretary of the Pacific Division of the American Phytopathological Society, University of Idaho, Moscow, Idaho.—C. W. HUNGERFORD.

Publication of foreign papers. In accordance with instructions given the Committee on International Phytopathology appointed by the Society at the Cincinnati Meetings, arrangements have been made with Dr. H. M. Quanjér, of the Phytopathological Institute of Wageningen, Holland, to act as editor of Phytopathology for Europe and to solicit subscriptions and to receive and transmit papers offered for publication in the Journal in

either English, French, or German, the total of such papers not to exceed 100 pages during the year. A special subscription rate has been offered in those countries whose currency is below par. Full information regarding this plan can be obtained from Dr. Quanjer. It is hoped that our European colleagues will accept this opportunity to advance our knowledge and bring about closer and better phytopathological relations.—C. L. SHEAR, *Chairman*.

The July number of Phytopathology was issued July 21, 1921.

PHYTOPATHOLOGY

VOLUME XIV

NUMBER 9

SEPTEMBER, 1924

THE VIABILITY OF UREDOSPORES

W. E. MANEVAL

Many observations and tests have been made on the longevity of uredospores of rusts. The spores have been kept under various conditions, both in the open and indoors. Conclusions as to overwintering out of doors are sometimes doubtful, since mycelium may live through the winter and spores present in the spring may have developed during the winter or early spring. Freeman and Johnson (2) after reviewing the literature regarding overwintering of uredospores out of doors pointed out that previous conclusions were frequently based on opinion rather than on accurate observations. They obtained viable uredospores of *Puccinia graminis* throughout the winter from living hosts in the open, and as late as March 20 from plants buried in the snow from December 10 to that date. Likewise uredospores of *Puccinia rubigo-vera* and of *Puccinia simplex* buried in the snow germinated to March 20. It is probable that no development of spores occurred beneath the snow.

Various records, however, of tests with spores whose age was positively known show beyond doubt that uredospores of certain rusts may live a considerable time or through the winter either in the open or indoors.

Ward (9) succeeded in germinating uredospores of *Puccinia dispersa* (Erikss.) that had been kept dry in a tin box for 61 days. Fromme (3) reported a very low per cent (0.2) of germination in the case of uredospores of *Puccinia coronifera* that had been kept at room temperature for 84 days (Nov. 26-Feb. 18). He also gives records for various other rusts.

Reed and Holmes (6) tested uredospores of *Puccinia coronata* Cda. from volunteer oat plants that died December 1, and were left in the field through the winter. Twenty per cent of the spores germinated February 15, but only 5 per cent in a test marked "doubtful" March 1. However similar tests with spores from living plants in the open gave positive results to January 5, and negative results January 15. Increasing percentages of spores germinated from February 1 to April 1. The authors therefore supposed that the uredospores had died by January 15, but that mycelium remained alive and began producing new spores before February 1.

Melhus and Durrell (4) tested uredospores of *Puccinia coronata* C'da. after storing 55 days in dry capsules at 13° C. and secured twenty per cent of germination, but no germination if the spores were stored under similar conditions at either 6° C. or 20° C.

Peltier (5) found that the longevity of uredospores of *Puccinia graminis tritici*, Form III, depended on temperature and humidity. Spores stored at 25° C. and 49 per cent humidity germinated after 5 weeks but not after 6 weeks. At temperatures from 5°–15° C. with the humidity varying from 38–70 per cent the spores still germinate at the end of sixteen weeks.

Miss Fraizer (1) secured fair germination of uredospores of *Puccinia helianthi* which had been kept between sheets of blotting paper for 111 days (Nov. 20–March 10) at room temperature. Spores of the same rust collected September 10 and kept in an ice chest still germinated quite well (25 per cent) after 182 days.

Spaulding (7) reports that York, Overholts and Taylor found uredospores of *Cronartium ribicola* that had been dried in a plant press still viable after storage for 80 days in tight Mason jars kept in an ice chest. Besides uredospores in the open protected from rain germinated after 100 days; spores on leaves kept between sheets of glazed paper germinated after 169 days; and successful inoculations were secured with spores that had overwintered and were 270 days old. Miss Taylor (8) a year later also obtained successful infections with overwintered uredospores of this rust.

Various additional records might be cited indicating or proving that uredospores of various other rusts may live from two to six months, either in the open or when stored under more or less definite conditions of temperature and humidity. During the past two years the writer has tested the viability of uredospores of several species of rusts. The spores were collected at Columbia, Missouri, generally late in the fall, and after drying were kept in a cool (5–15° C.) room most of the time. In all cases the spores were allowed to remain on the host. At intervals germination tests were made by floating the spores on distilled water in small preparation dishes and incubating at room temperature for one or two days. In the records that follow the percentage of germination is generally not expressed definitely, but the approximate amount of germination is indicated.

Uromyces striatus Schr. on *Medicago sativa* L.

Uredospores of this rust were collected November 11, 1922, and kept in a cool room. No tests were made until March 23, 1923, when a fairly large proportion of spores germinated. Subsequent tests on March 31, April 13 and 20, and May 7, gave positive results but no spores germinated in a final test June 9. Collections of uredospores of March 3 and April 2, 1923, failed to germinate. Uredospores were also collected October 9, 1923, and

kept at room temperature until November 14, after which they were stored in a cool room. A high percentage of spores germinated November 14. Subsequent tests resulted as follows: December 12, fairly high per cent of germination; January 4, 10–15 per cent; February 1, few spores; February 27, numerous spores; March 29, $1 \pm$ per cent; April 17, negative. Spores of this rust therefore remained viable for at least 173 to 178 days after collection.

Infection experiment.—In the spring of 1923 ten alfalfa plants were dug up, transferred to the greenhouse and potted. No rust was found in the field where these plants grew during the seasons of 1922 nor 1923. Six plants were inoculated with spores collected November 11, 1922. After inoculation the plants were kept in moist chambers for a suitable length of time. The other four plants were used as checks. Since the percentage of viable spores was small and no pustules had appeared by May 7, four of the plants were reinoculated on this date. The checks all gave negative results while the results with the inoculated plants were as follows:

Inoculated	Uredo pustules
1. 4/24 and 5/7	6/13—1 leaf; 6/18—4 leaves
2. 4/20 and 5/7	Negative
3. 4/24 and 5/7	6/18—1 leaf
4. 4/18 and 5/7	6/18—1 leaf
5. 4/20	6/19—1 leaf
6. 4/18	Negative

It seems, therefore, that uredospores of *Uromyces striatus* may not only retain their ability to germinate for nearly six months but also to infect alfalfa.

Puccinia sorghi Schw. on *Zea Mays* L.

Uredospores collected November 11, 1922, and stored in a cool room germinated to some extent when tested April 2, 1923. Spores collected November 6, 1923, on young (volunteer) corn plants killed by frost were kept in a cool room and tested at intervals of about a month. A very high percentage of spores germinated up to January 4. The results of later tests were as follows: February 1, rather low per cent; February 27, 10–15 per cent; March 29, $10 \pm$ per cent; April 17, 1 — per cent. A third collection from nearly mature corn plants, October 2, 1923, was kept at room temperature until November 14, and after that in a cool room. When last tested, April 17, 1924, between 1 and 5 per cent of spores germinated. So in these tests uredospores remained viable at least 143 days after collection in 1922 and 168 to 180 days the next year.

Puccinia coronata Cda. on *Avena sativa* L.

Uredospores of this rust were collected October 18 and November 2, 1923. Both collections were kept at room temperature until November 6, and after that date in a cool room. Tests at approximately monthly intervals gave positive results to March 29, and negative results April 17. From 1-5 per cent of spores collected October 18, still germinated March 29, but only an occasional spore of the later collection. Some of these spores therefore continued to germinate for 149 to 164 days after collection.

Puccinia menthae Pers. var *Americana* Burr. on *Monarda fistulosa* L.

Uredospores collected October 9, 1923, were kept at room temperature till November 14, and later in a cool room. In tests similar to those above some spores continued to germinate until March 29, but none at the next test on April 17. Hence some of these spores retained their ability to germinate at least 173 days after collection.

Uromyces caryophyllinus (Sch.) Wint. on *Dianthus caryophyllus* L.

Uredospores were collected on living carnations in the greenhouse November 17, 1923, and after drying were stored in a cool room. A very high percentage of spores germinated when tested November 17 and December 12, and fewer January 4 and February 1. However, $25 \pm$ per cent still germinated February 27, from 1-5 per cent March 29, $10 \pm$ per cent April 17, $1 \pm$ per cent May 3 and 1 — per cent May 19. It is evident from these tests that some uredospores of this rust may remain viable at least 185 days.

Puccinia amorphae Curt. on *Amorpha fruticosa* L.

Uredospores collected October 8, 1923, were kept at room temperature until November 14, and after this date in a cool room. Positive results in germination tests were obtained to January 4, but none on February 1, or later. These spores therefore remained viable for at least 89 days after collection.

SUMMARY OF RESULTS REFERRED TO ON VIABILITY OF UREDOSPORES

Ward, *Puccinia dispersa* (Erikss.) 61 days.

Fromme, *Puccinia coronifera* 84 days.

Reed and Holmes, *Puccinia coronata* Cda. 77 (91?) days.

Melhus and Durrell, *Puccinia coronata* Cda. 55 days.

Peltier, *Puccinia graminis*, Form III 92 days.

Fraizer, *Puccinia helianthi* 182 days.

Spaulding, *Cronartium ribicola* 80; 100; 169; 270 days.

Taylor, *Cronartium ribicola* Overwintered.
Maneval, *Uromyces striatus* Schr. 173; 178 days.
Maneval, *Puccinia sorghi* Schw. 143; 168; 180 days.
Maneval, *Puccinia coronata* Cda. 149; 164 days.
Maneval, *Puccinia menthae* Pers. var. *americana* Burr. 173 days.
Maneval, *Uromyces caryophyllinus* (Sch.) Wint. 185 days.
Maneval, *Puccinia amorphae* Curt. 89 days.

These records for 10 species of rusts show that at least 7 of them may live approximately 6 months at rather cool temperatures and moderate humidity. Judging from the behavior of these it is probable that under certain conditions uredospores of many other species would retain their germinating power from 3 to 6 months, or even longer. It is very probable that such conditions sometimes exist in nature, and particularly in barns in stored hay, and so forth. Hence it is very likely that rusts such as those of corn, alfalfa and oats may overwinter in the uredo stage, be disseminated and become established in the spring.

LITERATURE CITED

1. FRAIZER, EUNICE. Student thesis, University of Missouri, 1920.
2. FREEMAN, E. M., and E. C. JOHNSON. The rusts of grains in the United States. United States Dept. Agric. Bur. Plant Ind. Bul. 216. 87 p., 2 fig., 1 pl. 1911. Bibliography, p. 79-82.
3. FROMME, F. D. The culture of cereal rusts in the greenhouse. Bul. Torrey Bot. Club 40: 501-521. 1913. Literature, p. 519-521.
4. MELHUS, I. E., and DURRELL, L. W. Studies on the crown rust of oats. Iowa Agric. Exp. Sta. Res. Bul. 49: 115-144. 6 fig. 1919. Bibliography, p. 143-144.
5. PELTIER, G. L. A study of the environmental conditions influencing the development of stem rust in the absence of an alternate host. Nebraska Agric. Exp. Sta. Res. Bul. 22. 15 p., 3 fig. 1922.
6. REED, H. S., and F. S. HOLMES. A study of the winter resistance of the uredospores of *Puccinia coronata* Cda. Ann. Rept. Virginia Poly. Inst. Agric. Exp. Sta. 1911-1912: 78-81. 1913.
7. SPAULDING, PERLEY. Investigations of the white-pine blister rust. United States Dept. Agric. Bur. Plant Ind. Bul. 957. 100 p., 6 pl., 13 fig. 1922. Literature cited, p. 90-100.
8. TAYLOR, M. W. The overwintering of *Cronartium ribicola* on *Ribes*. Phytopath. 9: 575, 1919.
9. WARD, H. M. Further observations on the brown rust of the bromes, *Puccinia disspesa* (Erikss.) and its adaptive parasitism. Ann. Mycol. 1: 132-151. 1903. Bibliography, p. 151.

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LONGEVITY OF CULTURES OF FUSARIA

W. E. MANEVAL

In a recent number of *SCIENCE* Miss McCrea (5) points out that thoroughly reliable records concerning the longevity of spores of fungi are not very numerous. Miss McCrea germinated spores of *Aspergillus oryzae* which had been preserved, after drying in the air, at an ordinary temperature in a sealed tube for twenty-two years. *Rhizopus nigricans* also developed from the spore dust used in these tests and so it seems that viable spores of this fungus too were present in the sealed tube.

Various similar records, but generally for shorter times, may be found in the literature. For the smuts De Bary (1, p. 344) cites the record of Liebenberg, according to which spores of various species of *Ustilago* and *Tilletia*, kept as herbarium specimens, lived from $3\frac{1}{2}$ to $8\frac{1}{2}$ years. Other investigators of smuts have obtained similar results. Wehmer (6) kept pure cultures of 2 species of fungi in diffuse light at room temperature about $2\frac{1}{2}$ years, the culture vessels being plugged with cotton. On transferring to a sterile sugar medium 7 species failed to develop, 8 grew at once, and 6 after several weeks. In the case of these 6 species growth was obtained only after pouring a sterile medium into the original cultures. The fungi tested were mainly *Phycomyces* and species of *Aspergillus*. Lafar (4, p. 201) cites earlier records of Wehmer for *Aspergillus wentii* (1 + year), *A. niger* ($3 \pm$ years) and *A. oryzae* (4 + years). Lafar also refers to the work of Eidam, Hansen and Brefeld indicating that spores of *A. flavus*, *A. fumigatus* and *A. glaucus* may remain viable for 6, 10 and 16 years respectively. Hansen (2) kept perithecia of *Anixiopsis stercoraria* dry in paper folders from 1874 to 1895. Transfers of ascospores were then made to a wort-gelatine medium and in a few days a vigorous, practically pure vegetative growth of *Anixiopsis* developed. Kurzwelly (3) found that spores of *Phycomyces nitens* dried in air died in a comparatively short time but if dried in a dessicator and stored in absolute alcohol still germinated after 2 years and 2 months.

In the spring of 1916 the writer placed stock cultures of species of *Fusarium* labeled as follows in an ice chest:

- (1) *Fusarium conglomerans*
- (2) *Fusarium nivum*
- (3) *Fusarium oxysporum* Schlecht.
- (4) *Fusarium vasinfectum* Atk.
- (5) *Fusarium discolor* App. and Wollen.
- (6) *Fusarium gibbosum*

- (7) *Fusarium coeruleum* (Lb.) Sacc.
- (8) *Fusarium solani* (Mart.) Sacc.
- (9) *Fusarium trichothecioides* Wr.
- (10) *Fusarium discolor* var. *sulphureum* (Schlecht.) App. and Wollenw.

The test tubes containing the cultures were plugged with cotton and the fungi were growing on stems, except *Fusarium discolor* and *Fusarium discolor* var. *sulphureum* which were on agar. All of the cultures were obtained by Dr. George M. Reed in the spring of 1916. The culture of *F. conglomerans* was received from the University of Wisconsin, and had been isolated from diseased cabbage January 14, 1913. The culture of *F. nivum* was obtained from C. W. Carpenter of the U. S. Department of Agriculture. The writer does not know the exact source of the other eight species, but it seems that they were all obtained from the same source, very probably from the U. S. Department of Agriculture. All apparently were authentic cultures.

Duplicate transfers from these cultures were made to potato dextrose (2 per cent) agar March 6, 1924, and allowed to incubate at room temperature. By March 10 growth in both tubes of *F. oxysporum* and of *F. conglomerans* was evident and in one tube of *F. vasinfectum*. On this date the entire piece of stem in the case of *F. gibbosum* was transferred and to the other tubes in which there was no growth a second transfer of spores and mycelium was made. On March 15 growth was evident in the second tube of *F. vasinfectum* and in the tube of *F. gibbosum* containing the piece of stem. Two or three days later pieces of agar or else stems were transferred in the case of the 6 species that had not grown. Positive results were obtained from these transfers by March 24, with *F. nivum*, *F. discolor*, *F. trichothecioides* and *F. solani*, but the other 2 species (*F. coeruleum* and *F. discolor* var. *sulphureum*) never grew. So after being preserved for approximately 8 years at a temperature near 10° C., most of the time, in test tubes plugged with cotton and in a rather moist atmosphere eight out of the ten species of *Fusaria* tested grew more or less readily.

One of the recommendations for control of diseases caused by species of *Fusarium* is a rotation of 5 to 8 years, based on the fact that a particular species of the fungus, if once established in the soil, would persist for several years. In such cases however it is probable that new growth occurs to some extent every year. In the stored cultures used in these tests it is likely that no new growth occurred after the first few weeks of storage in the ice chest and so the evidence is practically conclusive that either spores or mycelium or both remained viable for between 7 and 8 years.

LITERATURE CITED

1. DEBARY, A. Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria. 525 p., 198 fig. 1887. (English trans. by E. F. Garnsey, M.A.), Oxford.
2. HANSEN, E. CHR. Biologische Untersuchungen über Mist bewohnende Pilze. Bot. Zeitung. 55: 111-131. 1897.
3. KURZWELLY, WALTHER. Ueber die Widerstandsfähigkeit trockener pflanzlicher Organismen gegen giftige Stoffe. Jahrb. f. wiss. Bot. 38: 291-341. 1902.
4. LAFAR, FRANZ. Handbuch der technischen Mykologie 1: 200-202. 1904-7.
5. MCCREA, ADELIA. Longevity in spores of *Aspergillus oryzae* and *Rhizopus nigricans*. Science, N. S., 58: 426. 1923.
6. WEHMER, C. Über die Lebensdauer eingetrockneter Pilzkulturen. Ber. d. d. Bot. Gesell. 22: 476-478. Pl. 2. 1904.

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THE USE OF SULPHUR AS A FUNGICIDE AND FERTILIZER FOR SWEET POTATOES

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WITH FOUR FIGURES IN THE TEXT

Experimental work with inoculated sulphur during the growing seasons of 1922 and 1923 has established evidence of its importance as a fungicide and fertilizer for sweet potatoes under Delaware conditions. Scurf, pox and black rot diseases have been reduced in prevalence and increased yields and improved keeping qualities of sweet potatoes have been experienced where the inoculated sulphur was used.

During 1922, four experiments were established to determine the effectiveness of inoculated sulphur for the control of scurf (*Monilochaetes infuscans* E. and H.) and pox (*Cytospora batatis* Elliott).¹ The experiments were established in cooperation with growers in Houston, Scaford, Laurel and Delmar, which are the principal centers of the commercial production of sweet potatoes in Delaware. One acre and half acre plots were used, and the soil was of the sassafras series. The results of the experiments for 1922 are summarized in table 1.

TABLE 1.—Results with inoculated sulphur on yield of sweet potatoes and disease control during 1922

Experiment	Fertilizer per Acre	Inoculated Sulphur per Acre	Soil Reaction at Harvest	Total Yield Primes, Seconds and Strings	Increase	Scurf	Pox
1	Lbs.	Lbs.	pH	Bu.	Bu.	%	%
Treated	1,200 of a 4-7-15	200 Broadcast	4.58	404.0	102.0	Trace	0
Check	"	"	4.43	302.0		6	0
2							
Treated	1,000 of a 2-8-10	400 Broadcast	3.90	296.3	98.8	Trace	40
Check	"	and drilled	4.70	197.5		15	95
3							
Treated	1,000 of a 5-7-5	400 Drilled	3.79	250.0	64.8	1	0
Check	"	"	4.98	185.2		35	0
4							
Treated	1,500 of a 2-8-10	300 Top Dressing	4.72	270.0		10	0
Check	"	"	4.80	270.0		30	0

¹ This disease has been generally reported as being caused by the slime mold described by Elliott as *Cytospora batatis*. This is not in agreement with the writer's findings who considers that the causal pathogene remains to be determined.

In experiment 1, the "Big Stem" variety of sweet potato was used and the plants set 18 x 32 inches. The inoculated sulphur was applied broadcast at the rate of 200 pounds per acre about three weeks before the sprouts were set. The total yield (primes, seconds and strings) is reported, which shows an increase of 102 bushels on the treated plot compared with the check plot. The total yield was computed by weight (one bushel weighing fifty-eight pounds) for one acre from the harvest of fifty hills in each plot. The tubers were nearly all of average prime size and a smaller percentage of strings than usual was found. The check plot showed 6 per cent prevalence of scurf as compared with only a trace in the treated plot.

The same variety of sweet potato was used in experiment No. 2 and the plants were set 18 x 42 inches. The inoculated sulphur was applied broadcast and also drilled in the row at the rate of 200 pounds per acre for each application. The field in which the experiment was located had been cropped continuously in sweet potatoes for over ten years. The prevalence of pox had been of increasing severity, and the crop in 1921 showed 100 per cent infection. Considering the past history of the sweet potato crops in this field, the yield in 1923 was very superior. The total yield was secured at harvest time in five-eighths baskets for each acre plot. The sulphur treated plot gave an increase of 98.8 bushel over the total yield of the check. The prevalence of 15 per cent scurf and 95 per cent pox in the check plot were reduced respectively in the sulphur treated plot to a trace and 40 per cent. The pox symptoms were most prevalent upon the larger fleshy roots and were of a shallow type, indicating that infection had become established during the latter part of the growing season. The sweet potatoes from the sulphur treated plot were much cleaner and much brighter in appearance.

A mixture of two varieties, "Gold Skins" and "Big Stems," was used in experiment No. 3, and the plants were set 20 x 36 inches. The total yield reported was secured at harvest time in five-eighths baskets from one-half acre for each plot. The control of scurf in the sulphur treated plot was very conspicuous being reduced to 1 per cent as compared with a 35 per cent prevalence in the check plot. As the result of contact of the roots with the sulphur, a reddish pigmentation of the fleshy roots was found in some hills. The nature and extent of this skin coloring was not of sufficient importance to interfere with their marketable value. The increase yield from the sulphur treated plot was 64.8 bushel over the total yield of the check plot.

The "Yellow Jersey" variety of sweet potato was used in experiment No. 4 and the plants were set 17 x 32 inches. The inoculated sulphur in this experiment was applied as a top dressing two weeks after the sprouts were planted. The total yield was not measured in this experiment, but it was estimated by the grower at 270 bushels and with no difference in yield on the two plots. The prevalence of scurf was reduced from 30 per cent in the

check to 10 per cent in the treated plot. Black rot was only slightly prevalent, and the examination of the harvested crop failed to show any noticeable differences in the amount of disease prevalence in the two plots.

The growing season of 1922 was very favorable for growth of sweet potatoes and yields above normal were generally reported by growers. Experimental results with inoculated sulphur during 1922 showed decided increases in yield, and a reduced prevalence of plant diseases. Soil samples were taken at harvest time and the soil reaction determined by the electrometric method and the hydrogen-ion concentration reported as the pH exponent.¹ These results are shown in table 1, and it was found that the soil acidity had been increased in each experiment except experiment No. 1. While consistent increased yields and plant disease control were secured, there was no definite correlation with the increased acidity. The increased yields show some evidence of the relation of yield to the amount of potash in the various complete fertilizers used. A more detailed analysis in this respect is hardly warranted with this preliminary work but will be taken up in the general discussion on the two years work.

The experimental work was continued during 1923 at Houston and Delmar. At Houston, two different experimental plots of one acre each were used. In the experimental plot for pox control the variation in the soil of the experimental field was such as to make it more practical to report the results as experiments No. 5 and No. 6 as given in table 2. The variety of sweet potato grown in the three experiments as reported in table 2 was the "Big Stem" and the plants were set 18 x 42 inches.

TABLE 2.—Results of inoculated sulphur on yield of sweet potato and control of pox in 1923

Experiment	Fertilizer per Acre	Inoculated Sulphur per Acre	Soil Reaction			Clean Crop	Slight Pox	Severe Pox Not Salable	Primes, Seconds and Strings Salable Total Yield
			May	Aug.	Oct.				
5	Lbs.	Lbs.	pH	pH	pH	Bu.	Bu.	Bu.	Bu.
Treated	1,000 of a 2-8-8	300 Broadcast	5.16	4.54	4.13	83.5	214.2	30.9	297.7
Check	"	"	5.33	5.86	5.03	32.1	143.0	98.9	175.1
6	"	300 Broadcast				176.6	266.6	3.3	443.2
Treated Check	"	"				113.4	166.6	60.0	280.0
7	"	200 Broadcast		5.00	4.12	318.1			318.1
Treated Check	"	"		5.93	6.03	259.9			259.9

¹The soil reactions were all determined by Professor Tarr, head of the Chemistry Department.

In experiment No. 5, the soil was of the sassafras loam type which has in previous years received frequent applications of manure. The soil contained a higher content of organic matter than the soil in any of the other experiments. Sweet potatoes harvested from this ground in 1922 showed heavy infection of pox. The yield reported in table 2 was computed from a



FIG. 1. Top. Results of keeping qualities of one bushel of sweet potatoes after two months in storage from sulphur-treated plot in Exp. No. 5. Clean sweet potatoes on left, Black Rot sweet potatoes in middle and Soft Rot sweet potatoes on right. See table IV.

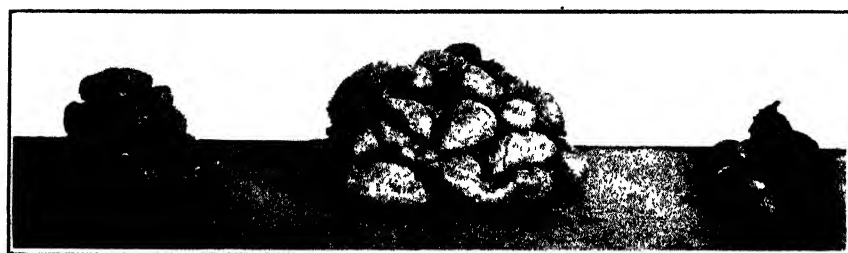


FIG. 2. Results of keeping qualities of one bushel of sweet potatoes after two months in storage from check plot in Exp. No. 6. Clean sweet potatoes on left, Black Rot sweet potatoes in middle and Soft Rot sweet potatoes on right. See table IV.

composite sample made up of twenty-eight hills each from two different rows. The evidence shows a material control of pox and an increased total yield as well as an increased commercial yield on the sulphur treated plot as compared with the check. There was an increase of 3.6 per cent of primes from the treated plot over the total of primes from the check. The sweet potatoes from the treated area were much brighter in color and seemed more crisp in handling.

Experiment No. 6 was located on a soil of the light sassafras type but was similar to the preceding experiment in so far as the use of fertilizer and the variety of sweet potato used. The yield reported in table 2 was

computed from a composite sample made up of twenty hills each in two different rows of sweet potatoes. The actual commercial yield in primes showed a ten per cent increase for the sulphur treated plot. The amount of severe pox infection was much less than in the preceding experiment, where there was more organic material in the soil. The treated area com-

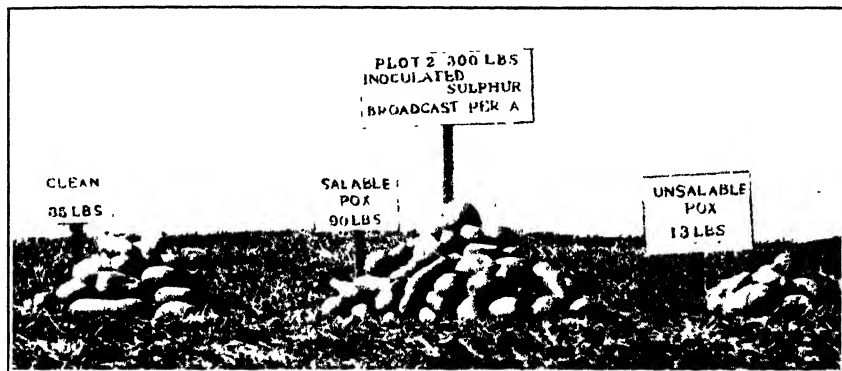


FIG. 3. Yield from twenty-eight hills of sweet potatoes in sulphur-treated plot of Exp. No. 5.

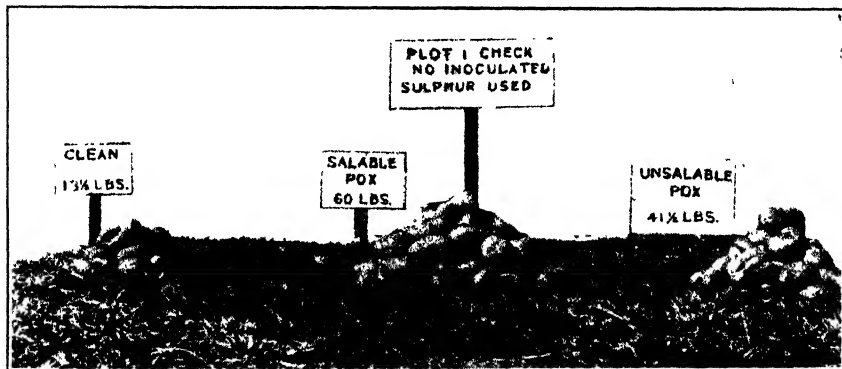


FIG. 4. Yield from twenty-eight hills of sweet potatoes in check plot of Exp. No. 5. The twenty-eight hills were consecutive and in parallel rows from each plot.

pared with the check showed an increase of 55.7 per cent of clean roots, 60.3 per cent of commercial roots and a decrease of 93.8 per cent for roots not commercial.

In experiment No. 7, the variety of sweet potato and fertilizer used were similar to the preceding experiment except that a reduction of 100 pounds per acre of inoculated sulphur was made. The total yield reported shows

a practical increase for the treated area but not as marked as in the two preceding experiments. There was practically no trace of scurf or evidence of black rot in either plot.

In experiment No. 6, the actual commercial yield showed a prevalence of 2.23 per cent of black rot for the treated area and 8.5 per cent for the check. At the time of harvest October 9, 1923, there was an apparent reduction of black rot on the sweet potatoes from the treated area. In the majority of the instances of heavy infection, black rot appeared to have become established through the lesions caused by the pox infection. At the time of harvest, the question was raised as to whether or not there was an actual control of black rot or an apparent reduction because of the better pox control. Further evidence in relation to the question of the control of black rot is indicated in the results secured on the keeping qualities of the sweet potatoes in storage. Round bushel baskets were used in which to store the potatoes and they were filled in the field by the grower in the same manner as the commercial harvest was made in the standard $\frac{5}{8}$ baskets. The baskets were placed in the upper loft of a heated storage house and examination was made on December 10 at which time the data reported in table 4 was secured. The results as far as the control of soft rot was concerned were consistent. Soft rot may become established through careless handling at harvest and in storage. More extensive studies are essential before any definite conclusion may be drawn. Soft rot was more generally prevalent at harvest time during 1923 than during the previous three years. While the storage period was only of two months duration, the

TABLE 3.—*Results of inoculated sulphur on yield of sweet potatoes and control of scurf in 1923*

Experiment 8	Fertilizer per Acre	Inoculated Sulphur	Soil Reaction		Crop Primes Clean	Crop Primes with Scurf	Crop Secon-onds Clean	Crop Secon-onds Scurf	Total Com-mercial Yield	% Scurf
			June	Oct.						
Plot 1	5 tons Manure and 1,000 lbs. of a 3-7-5	Lbs. 150	pH 5.50	pH 5.50	Bu. 207.1	Bu. 52.80	Bu. 47.0	Bu. 5.4	Bu. 312.3	22.8
Plot 2 Received 400 lbs. of sulphur in 1922	"			5.20	91.5	91.5	91.5	10.9	285.4	55.9
Plot 3 Check	"		5.81	5.64	135.5	65.1	66.9	5.3	272.8	34.7

results were sufficient to indicate that the sulphur treatment in the field had an influence on the keeping qualities and upon black rot development in storage. The evidence is presented as a preliminary report and the results are of such a promising nature that more extensive studies should be conducted.

The experiment established in Delmar during 1923 is outlined in table 3. A mixture of "Gold Skins" and "Big Stems" was used in experiment

TABLE 4.—*The relation of inoculated sulphur treatment for sweet potatoes on the development of black rot after sixty days' storage*

	From Treated Plot			From Check Plot		
	Basket 1			Basket 1		
	No. Potatoes	Lbs. Potatoes	% in Lbs.	No. Potatoes	Lbs. Potatoes	% in Lbs.
Sound	43	26.3	62.3	20	10.5	24.8
Black Rot	15	11.6	27.4	35	27.9	65.9
Soft Rot	9	4.5	10.6	9	3.9	9.2
Total	67	42.4	100.3	64	42.3	99.9
	Basket 2			Basket 2		
Sound	61	36.25	83.8	27	15.5	37.1
Black Rot	6	2.75	6.5	27	23.5	56.2
Soft Rot	6	4.25	9.8	5	2.75	6.6
Total	73	43.25	99.9	59	41.75	99.9

No. 8. Each plot consisted of one acre. The total commercial yield was computed at harvest time in five-eighths baskets from one quarter of each acre plot. All three plots received an application of manure and a complete fertilizer. It is of special interest to note that in contrast to the other experiments an organic fertilizer was applied in addition to the mineral fertilizer. Plot 2 is the same area as used in experiment No. 3 during 1922 and was included to determine the residual effect of the 1922 treatment. However in this instance, the evidence indicates that the organic fertilizer increased the buffer action and decreased the acidity of the soil. Commercial increased yields were secured from the plots receiving sulphur treatment, but the control of scurf was not as marked as in the other experiments. It is evident that the addition of organic material favored greater prevalence of the scurf, even on the sulphur treated plots. No doubt better control would have been secured if the application of sulphur had been doubled.

Before discussing the experimental work conducted during 1922 and 1923, it should prove interesting to review some of the previous work with sulphur as a fungicide and fertilizer for potatoes.

Halsted (3) used flowers of sulphur at the rate of 2500, 1250 and 625 pounds per acre. He found that "sulphur gives the highest yield of clean roots which were very smooth, and fair, free from scurf and all cracks and disfigurements." In 1898, Halsted (4) found that sulphur alone and in combination with lime and kainit demonstrated that the total crop yield for the sulphured plots was nearly three times as much as for the untreated plots, and the weight of clean roots was more than ten times as much. "The experiments for the past four years show clearly that the soil rot may be held in check by sulphur, and the fungicide retains its power for a long time in the soil. It is also seen that kainit has a beneficial action, and with sulphur good crops of comparatively clean roots may be produced upon land thoroughly filled with the germs of the soil rot. The experiments indicate that three to four hundred pounds of both the sulphur and the kainit may be used, and the best results are to be effected when the two substances are mixed thoroughly in that portion of the soil where the new roots are to form." The large amounts of sulphur as originally used by Halsted are not considered practical in view of the experimental results secured in Delaware. Three to four hundred pounds of sulphur per acre are considered the practical limits for the most favorable results.

Chester (1) used sulphur at the rate of 265 pounds to the acre by applying a tablespoonful to the hill as each plant was set. He concludes that sulphur applied in this way probably has some decided effect in diminishing the black rot.

Taubenhaus and Manns (10) found that when seed is infected with black rot, sulphur is of no value as a treatment. Sulphur is also ineffective in preventing soft rot in the seed bed. Thus a mere sprinkling of it is all that is necessary for an excess of sulphur in the soil interferes with the proper sprouting and growing of seed. The harmful effect of the excessive use of sulphur is apparently due to the prevention of the movement of water through the soil as well as to excessive acidity.

Poole (7) has reported upon some extensive experiments with the use of sulphur and inoculated sulphur for the control of scurf and pox. The studies on pox control showed that sulphur broadcasted at the rate of 200 and 400 pounds per acre decreased the per cent of infection and the slight control appeared to increase the yield. It was found that a higher per cent of nitrogen than is used on a normal sweet potato soil is advised for infected soils. Soil acidity is suggested as having some relation toward the reduction of disease. The scurf disease was reduced to a minimum by sulphur, and

inoculated sulphur. The scurf fungus was most virile under normal moisture conditions in the presence of an abundance of organic matter.

In summarizing the work with sulphur and inoculated sulphur, it has been found that consistent and practical control of scurf and pox was secured. However, in none of the work reported upon have the variable factors been sufficiently uniform to derive accurately any specific correlations. Some of the variable factors that appear definitely related with disease control are soil type, soil reaction, temperature, moisture, organic matter and to a certain extent mineral fertilizers.

It has been found that scurf and pox are more generally prevalent where the soil contains a high organic content. On comparing the control of these two diseases in experiments No. 5 and No. 8, it is found that the reduction of disease prevalence is much less on those soil types with higher organic content. Increasing the amount of sulphur applications on such soil types no doubt would increase the disease control. It is difficult to correlate definitely the results in control where different soil types were used. Nevertheless, the results reported on the work for 1922 and 1923 are such that sulphur can be used on variable soil types in Delaware for securing disease control that will prove practical for the grower of sweet potatoes.

Soil reaction studies appear to show some relation to the disease control and increase yields. With but one exception, it was found that as the pH exponent decreased and the hydrogen-ion concentration increased the prevalence of disease decreased. When the sulphur is applied to the soil, it is assumed to be transformed into sulphuric acid which is known to possess certain fungicidal properties. It is difficult to state with the results secured whether this end product of sulphur oxidation has proved directly toxic or has created conditions possibly through other products that have resulted in the inhibition of the soil pathogenes. In considering the acidity resulting from the sulphur applications, there is also a question whether the restraint of fungus growth is due to the total acidity or to the toxicity of the soil acids. The increased vigor of plant growth, as indicated by the increased yields on the sulphur plots, is possibly a factor in the reduction of disease prevalence but cannot be considered as the primary factor. It is obvious that with but one exception, experiment No. 1, that sulphur applications have increased the soil acidity and resulted in decreasing the disease prevalence and increasing the yields. In experiment No. 1, the decrease in acidity with the sulphur treatment may be associated with the higher buffer reaction of the soil. This appears to be well illustrated in experiment No. 8 on plots 1 and 2 where manure was applied along with the mineral fertilizer and sulphur.

The soil type will unquestionably influence the amount of change in soil reactions through sulphur applications which complicate correlations with

the soil acidity in the work reported. Joffe (5) states that some soils deficient in sulphur may also be deficient in buffering agents. Since sulphuric acid, which is formed from sulphur oxidized, has a high dissociation constant; and the latter is also a measure of the concentration of the hydrogen-ion, then a small amount of sulphuric acid or any other inorganic acid will impart to a soil poor in buffers a high concentration of hydrogen-ions. It is evident that soils of such a nature, even though entirely free from sulphur, will not respond to sulphur applications. Extreme variation is to be expected in the capacity of soils to neutralize, absorb and adsorb the acids formed. Shedd (9) found that sulphur oxidation in sand was slower than in soil, the more fertile the soil, the more rapid the oxidation. His results are in keeping with those reported by Joffe (5), that peat has a beneficial influence on the oxidation of the sulphur in alkali soils and manure comes next.

The disease control secured through sulphur applications along with the increase yields indicates that soils with the high hydrogen-ion concentration are favorable to the growth of the sweet potato plant. There is evidence that as the pH exponent decreases and the hydrogen-ion concentration increases the yield increases. The increased vigor of growth as indicated by the increase yields for the experimental work reported may possibly be a partial factor in the disease control. It is evident that the sweet potatoes will be productive under conditions of soil acidity that are not tolerated by certain other farm crops. The two years work with sulphur indicates that the sweet potato is an acid-tolerant plant. For this reason continued cropping of sweet potatoes on the same soil is more practical if proper sanitation for the plant diseases is maintained. The residual effect of the sulphur applications on many soils, poor in buffers, would require a correction of the soil reaction that may not prove practical in the rotation of certain crops.

The relation of temperature is a factor in disease prevalence as well as in growth and development of the host in relation to the sulphur applications. The sweet potato plant appears to be productive under higher temperature conditions and these same conditions along with average rainfall are favorable for the soil pathogenes. The influence of temperature upon the soil pathogenes is probably a factor for increased infection that may be cumulative and in direct relation to the development of the host.

The increased yields secured with sweet potatoes during the experimental work of 1922 and 1923 with the applications of inoculated sulphur is sufficiently consistent to consider this element, or mineral, as a fertilizer or plant food for sweet potatoes in Delaware. The experiments reported upon during 1922 further show evidence that there is a correlation with the amount of potash used, as the increased yields are in proportion to the

potash content of the complete fertilizers and amount applied. In addition to the fungicidal and plant food value of the inoculated sulphur, it is a factor in making available other plant food in the soil. Joffe (5) states that the sulphuric acid produced by the oxidation of sulphur may be utilized for the unlocking of potassium from the insoluble silicates. Schermerhorn (8) in summarizing results of fertilizer experiments with sweet potatoes found that as the nitrogen increases and the potash decreases, the yield of marketable tubers decreases. The reverse was found when the potash was increased up to 8 per cent and the nitrogen decreased to 2 or 3 per cent, as there was a decided increase in yields. The results also show that the phosphoric acid apparently played but a small part in the production of sweet potatoes.

It is of interest to mention in connection with the increased yields reported with inoculated sulphur that Johnson *et al* (6) secured marked increased yields of sweet potatoes with sodium chloride as a top dressing applied at the rate of 1000 pounds per acre. In comparing sodium and potassium salts, it was found that top dressings of potassium sulphate and potassium chloride containing 50 per cent potash and sodium sulphate and sodium chloride of 98 per cent purity as top dressing gave increased yields over the check plots. They had a beneficial effect upon production. The sodium equivalent treated plots taken as a whole showed no superiority in yield over the potassium equivalent plots.

The improved keeping qualities of sweet potatoes in storage as the result of sulphur applications to the soil is of fundamental and economic importance. Poole (7) has found that sweet potatoes from plots receiving high amounts of nitrogen did not keep as well as the potatoes which grew on the plots that received mixtures containing high phosphate and potash compounds. Where sulphur was used, there was less shrinkage than where it was not used. The storage rots were less in the potatoes stored from plots treated with sulphur. He considers that the superior keeping qualities noted in potatoes grown on soils where sulphur was used is no doubt due to the condition of potato skin. No proof is advanced in support of this statement and it would be of further interest to determine if any physiological changes may be a factor. Many growers in Delaware are of the opinion that the larger amounts of phosphate used improves the keeping qualities of sweet potatoes.

The general sandy soil types used for sweet potato production in Delaware have shown their receptiveness to sulphur applications for the favorable production of sweet potatoes. The increased soil acidity resulting from the sulphur applications has proven favorable for the growth of the sweet potato host. The increased soil acidity resulting in some instances from sulphur applications has been found to be unfavorable for optimum growth

of certain crops like white potatoes, rye, wheat and corn. It is interesting to consider that Eaton (2) found that most of the sulphur of soils is in organic form. He states, "there is a general correlation between the sulphur and organic matter content, soils of a high organic matter content having in general a high sulphur content. The surface soils are in general higher in sulphur than the subsoils." Judging from the results obtained and the work of other investigators, sulphur fertilization should prove quite generally beneficial on the Atlantic coast and Gulf coast.

SUMMARY

The use of inoculated sulphur³ in Delaware has established evidence of its importance as a fungicide and fertilizer for sweet potatoes.

Consistent and practical control of scurf and pox have been secured and evidence that black rot is reduced in prevalence in the field as well as in development in storage on sweet potatoes where sulphur was used.

Consistent increased yields were secured where sulphur was used along with practical applications of a complete fertilizer.

Soil reaction studies appear to show some relation to the disease control and increased yields.

Results indicated that as the pH exponent decreased and the hydrogen-ion concentration increased the disease prevalence decreased.

There is evidence that as the pII exponent decreases and the hydrogen-ion concentration increases the yields increase.

It is considered as a result of the experimental work in Delaware that three hundred pounds of inoculated sulphur per acre is the maximum quantity essential for practical control and increase yields.

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LITERATURE CITED

1. CHESTER, F. D. The treatment of plant diseases in 1896. Delaware Agric. Exp. Sta. Bul. 34. 22 p. Illus. 1897.
2. EATON, S. V. Sulphur content of soils and its relation to plant nutrition. Bot. Gaz. 74: 32-58. 1922. Literature cited, p. 57-58.
3. HALSTED, B. D. Field experiments with potatoes. New Jersey Agric. Exp. Sta. Bul. 112. 20 p. Illus. 1895.
4. ———. Report of the Botanist. New Jersey Agric. Exp. Sta. Rept. 19: 289-370. 1898.
5. JOFFE, J. S. Biochemical oxidation of sulphur and its significance to agriculture. New Jersey Agric. Exp. Sta. Bul. 374. 91 p. 1922. Bibliography, p. 82-90.

³ The inoculated sulphur used for this experimental work was secured from the Texas Gulf Sulphur Company.

6. JOHNSON, T. C., ZIMMERLY, H. H., and GEISE, F. W. Effect of certain sodium and potassium salts on sweet potato production in eastern Virginia. *Proc. Amer. Soc. for Hort. Sci.* 1923: 155-162.
7. POOLE, R. F. Recent investigations on the control of three important field diseases of sweet potatoes. *New Jersey Agric. Exp. Sta. Bul.* 365. 39 p. Illus. 1922.
8. SCHERMEKHORN, L. G. Influence of fertilizers on the yield and form of the sweet potato. *Proc. Amer. Soc. for Hort. Sci.* 1923: 162-165.
9. SHEDD, O. M. The relation of sulphur to soil fertility. *Kentucky Agric. Exp. Sta. Bul.* 188: 595-630. 1914.
10. TAUBENHAUS, J. J., and MANNS, T. F. The diseases of the sweet potato and their control. *Delaware Agric. Exp. Sta. Bul.* 109. 55 p. 1915. Literature, p. 48-51.

A LABORATORY PROJECTION APPARATUS

REGINALD H. COLLEY

WITH PLATES XXVI AND XXVII

The general principles of optical projection have been so well explained by the Gages¹ that any lengthy discussion of them in a short article on general utility apparatus is unnecessary. The apparatus described below was designed by the writer primarily for photomicrography, but it has found its greatest usefulness as a projection apparatus for the study of sections of infected plant tissue and for the measurement of large numbers of fungus spores. The fact that it has served both purposes so well is the excuse for explaining its construction in detail. The methods of construction involve no essentially new principles; but the combination of old principles and tools has been worked up into a very useful piece of laboratory machinery.

The support for the optical bed is a roomy cabinet six feet long by two feet deep by three feet one inch high, with drawers and closets fitted to hold all the elements of the apparatus and any other supplementary equipment (Plate XXVI, figs. A and B). The cabinet is mounted on ball bearing casters. On the top of the cabinet rests a three inch layer of mattress felt, and on top of that the main part of the optical bed, a slab of steatite, or soap-stone, measuring six feet two inches long by two feet two inches wide, and two inches thick. The mattress felt is naturally compressed by the weight of the stone slab. Bolted to the top of the slab—which was planed smooth and flat at the factory—are two steel rails $\frac{3}{4}$ of an inch square in cross section (Plate XXVII). The bolt holes in the slab are made large enough to allow for some lateral adjustment of the rails. The rails are ordinarily held 10 inches apart and perfectly parallel. Their main purpose is to keep the projection apparatus in proper optical alignment.

The elements of the projection apparatus are a fixed rheostat, an arc lamp, a pair of condensing lenses and a slight shield, a water cell, and a microscope fitted with a right angle prism reflector. All of the elements are mounted on wooden blocks (Plate II). The blocks are built up, or constructed from thin pieces glued together, rather than cut from one single piece of wood, and so made that the end grain of the wood rests against the rails. This arrangement almost entirely avoids the jamming and sticking which would be inevitable as a result of swelling on damp days if the blocks were placed so that tangential or radial surfaces pressed against the steel.

¹ Optical Projection. Gage, Simon Henry, and Henry Phelps Gage. 731 p., 413 fig., Comstock Publishing Company, Ithaca, N. Y. 1914.

Adjustment to the correct optical axis is preferably made with the wooden base blocks against *one* rail, because in very dry weather the blocks sometimes fit a little loosely between the rails. Fine adjustment is then accomplished by centering the arc and the condensing lenses and spacing them so that the beam of light passes through the water cell and just about fills the bottom lense of the substage condenser of the microscope.

The substage condenser is of the centering achromatic type, easily adjustable for distance from the slide and to the correct optical axis. The microscope objectives are apochromatic, and they give better images with the arc as a source of illumination than the less fully corrected achromatic lenses. Compensating oculars are always used. The microscope is fitted with a mechanical stage.

In practice the apparatus is set up so that the microscope projects over the end of the steatite slab, as shown in Plate XXVI, figure A. The light is directed downward—by means of the right angle prism reflector—on an adjustable shelf table (Plate XXVI, fig. A). The table is then moved up or down until the image of a 10 micron division on a micrometer slide becomes 10 millimeters long on the table. The size of the image is determined by measuring with a standard white faced millimeter scale. The top of the table is covered with a sheet of white paper on which is drawn a four inch circle representing the central area of the illumined projected field. Distortion within this central area is at a minimum. Sizes in millimeters on the millimeter scale can be read directly as the sizes in microns of the objects.

The lenses ordinarily employed for study and spore measurement work are the 4 mm. objective, fitted with a collar for making the correction for cover glass thickness, and a number six compensating ocular. The observer can, of course, use the power best suited to the problem at hand. With the room properly darkened no difficulty has been experienced in the projection or study of images at a magnification of 2,500.

The observer who is skilled in making slides and in the technique of the microscope can do most satisfactory work with projection apparatus of the type described. There are certain mechanical difficulties in its use, but they are easily overcome with a little practice. It is obvious that water mounts cannot be handled on the horizontal microscope. Spores, or tissue which is not finished in balsam for example, should be mounted in some semi-solid medium which will not run at low heat. The glycerine and glycerine jelly combination described in an earlier paper¹ has proven very satisfactory. In no case, with this or any other medium, should the slide

¹ Colley, Reginald H. A Biometric Comparison of the Urediniospores of *Cronartium ribicola* and *Cronartium occidentale*. Journal of Agricultural Research.—In press.

become overheated as a result of being left too long in the path of the direct light of the arc.

The ideal way to use the equipment is with the help of an assistant who runs the arc, adjusts the substage condenser, places the slides in the mechanical stage, and takes down records, while the observer sits on a low chair and confines himself strictly to focusing and observing. His eyes are adjusted to the lights and shades of the image under such conditions, whereas, if he works alone they are continually thrown out of adjustment by the intense light of the burning carbons. Working alone, however, is simply a matter of getting accustomed to the necessary manipulations.

Much actual labor would be eliminated if a suitable incandescent lamp could be found to take the place of the arc. So far none of them have proven satisfactory for magnifications as high as 1,000. An accurate clock feed arc would probably be easier to handle than the hand feed arc but even with the clock feed some adjustment would occasionally be necessary to keep the light in the correct optical axis.

For photomicrography the elements of the projecting equipment are pushed to one end of the optical bed to leave room for the camera, also mounted on a wooden block, and the whole apparatus is set up as in Plate XXVI, figure B.

The felt and steatite slab arrangement is copied directly from apparatus in the offices of Dr. K. F. Kellerman and Dr. N. A. Cobb, of the Bureau of Plant Industry. No record has been found of the previous use of the simple combination of wooden blocks and square rails on the optical bed.

The whole apparatus is so heavy that minor shocks do not disturb a given set up at all. For that matter even the heavy vibrations caused by passing street cars were in most cases absorbed by the felt, so the equipment is sufficiently steady for all practical purposes. Additional light shields to keep light that escapes from the arc housing from striking the eyes of the observer, or from illuminating the room too much, and such additional equipment as focusing rods can be easily added to the apparatus if desired.

OFFICE OF INVESTIGATIONS IN FOREST PATHOLOGY,

BUREAU OF PLANT INDUSTRY,

WASHINGTON, D. C.

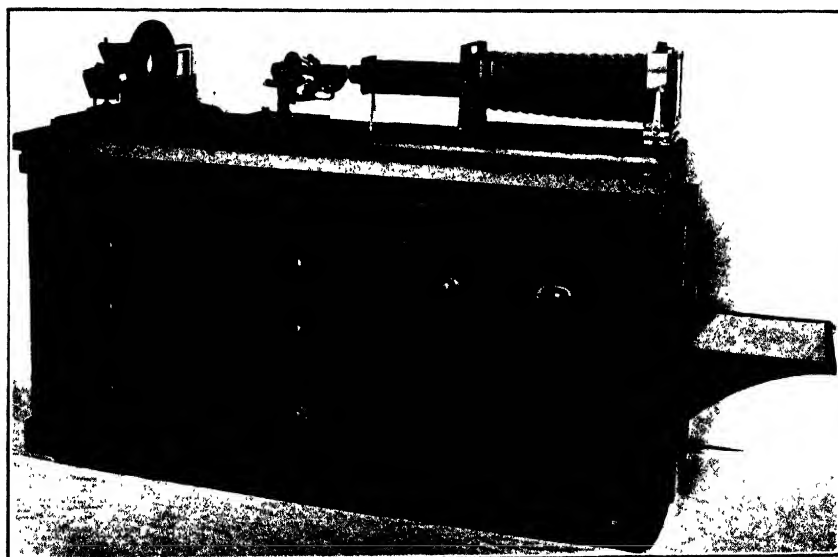
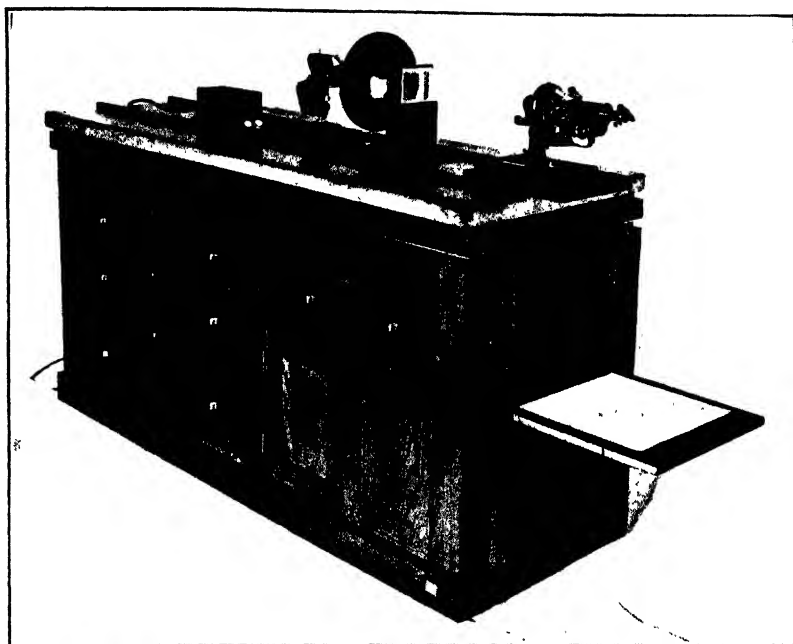
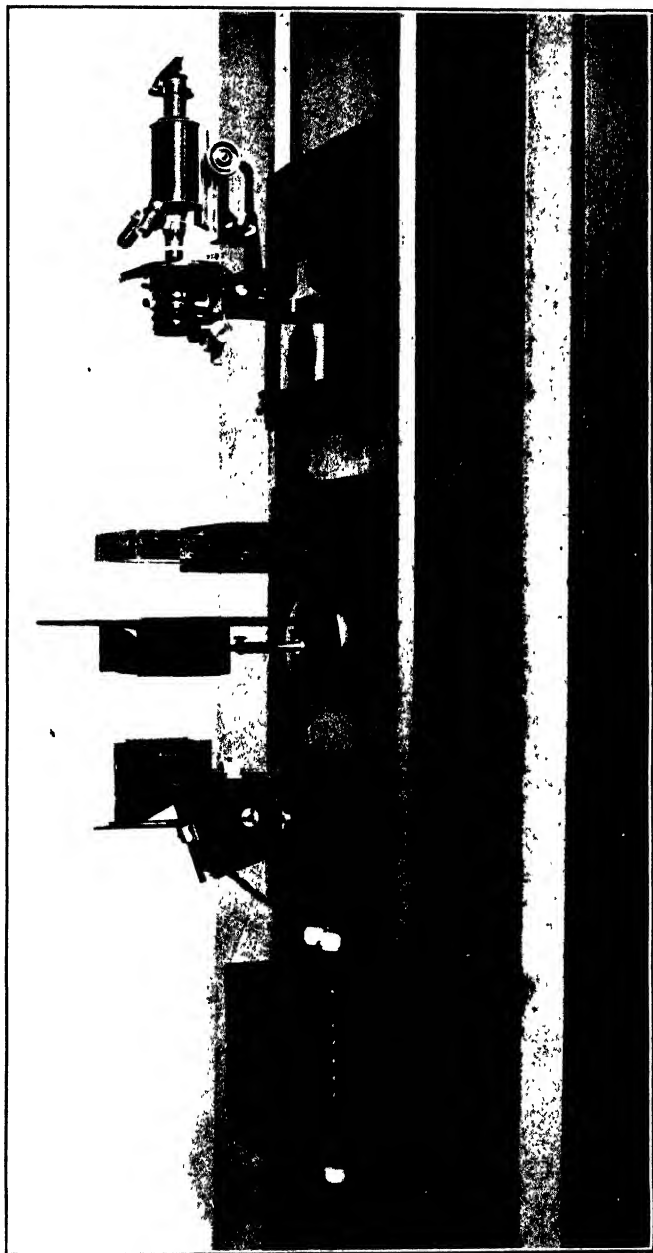


Fig. A (Upper). The apparatus set up for projection. The image is thrown upon the white paper on the adjustable shelf table. Fig. B (Lower). The apparatus set up for photomicrography.



The elements of the projection apparatus. From left to right: fixed rheostat, arc, condensing lenses with disk light shield, water cell, and microscope fitted with right angle prism reflector. The elements are held in the proper optical axis by the two steel rails bolted to the heavy steatite slab. Note the method of mounting the arc, the condensing lenses, and the microscope on the wooden blocks.

THE MANNER OF INFECTION OF PEACH TWIGS BY THE BROWN ROT FUNGUS

G. W. FANT¹

In the summer of 1922 there appeared in sections of New Jersey a blighting of peach twigs which caused considerable concern among peach growers. Some orchardists were inclined to attribute the condition to toxic spray materials, while it appeared possible to the writer and others that the brown rot fungus, *Sclerotinia cinerea*, might be responsible. While no endeavor was made by the writer to ascertain the cause for the twig blighting in the field, it was thought that a study of the conditions under which twig infection by the brown rot fungus takes place would be of value in determining the agencies responsible for various cankered areas often appearing on the younger growth in peach orchards. Previous to the appearance of the blighting in the field, inoculation experiments had been conducted by the writer to learn whether a wounded condition is essential for twig infection by the brown rot fungus. Other infection studies were made later in the season following the epidemic of twig blighting. It is the purpose of this paper to report the results obtained from these studies.

In these experiments the inoculation trials were made by applying an inoculum of brown rot conidia in sterile water to wounded and unwounded peach twigs. It has been shown by Jehle² that infection through wounds takes place readily on the limbs of the peach tree. Current year twigs and those of the previous season are relatively free from visible wounds so that widespread infection of young twigs, more especially those of the current year, is associated with the problem of whether or not the fungus has the ability to penetrate the unbroken epidermis.

In the infection studies, shoots of the current year and of the previous year's growth were employed. Two series of infection trials were undertaken—the first in early spring and the second in midsummer. In this manner it was possible to subject the current year twigs when first formed in the spring and when more mature in the summer to the inoculum of brown rot conidia.

In the first series, which was undertaken in April and May, moist chambers were used which consisted of inverted bell jars placed upon small platforms in which a small opening was left for inserting the twig to be

¹ Paper No. 183 of the journal series, New Jersey Agricultural Experiment Stations, Department of Plant Pathology.

² Jehle, R. A. The brown rot canker of the peach. *Phytopathology* 3: 105-110. 1913.

inoculated. Twigs were selected which were free from visible wounds. The inoculum was applied with an atomizer. The bell jars were lined with blotting paper moistened with sterile water. For a period of from three to five days following these inoculations, the atmosphere within the moist chambers was kept saturated by putting sterile water on the blotting paper. In this manner it was possible to maintain the original droplets laden with conidia upon the surface of the twigs for a period of several days. At the end of one week following inoculation, the moist chambers were removed and the twigs were observed at intervals throughout the remainder of the season. The series consisted of six infection trials and, with the exception of one twig accidentally wounded in setting up the moist chamber, none of these showed evidence of infection.

The second series, undertaken in midsummer, was conducted with hollow celluloid cylinders serving as moist chambers. In some instances, only the tips of new shoots were sprayed with inoculum and inserted, while in others the twigs extended entirely through the cylinders. Absorbent cotton moistened with sterile water was placed within the cylinder to maintain a high relative humidity, and the ends of the cylinder were plugged with cotton. Water was applied as often as necessary in order to maintain saturation. At the end of one week, the cylinders were removed. No twig blighting resulted from this series of inoculations.

In a number of instances twigs were collected several weeks following petal fall, which showed distinct brown rot cankers surrounding the base of the blossom pedicels. It has been shown by Jehle¹ and others that cankers may come about through blossom infection. This form of infection is of course confined to twigs one year old or older. When such twigs are placed in moist chambers, conidial pustules soon appear upon the surface of the lesions. This indicates that the lesions are caused by the brown rot fungus and that undoubtedly the blossom serves as a point of entry for the fungus. From our observations, it would seem further that infection first of the blossoms and then of the twigs is most common when the blossoms have been subjected to injury from freezing.

The development of cankers in the loci of wounds as reported by previous investigators has already been referred to. In the experiments of the writer, when twigs were injured and the inoculum was applied to the wounds, brown rot cankers developed in all cases. These cankers continue to enlarge for several months, though no data are at hand concerning the length of the period of activity of the fungus in cankers. Still another form of fungus entry is that brought about by the contact of the mummy with the branch,

¹ *Loc. cit.*, p. 108.

and this type of entry has been ascribed to fungous penetration through the fruit spur.¹

From the experiments reported in the preceding, the conclusion is drawn that the unwounded peach twig whether newly formed or of the previous year's growth is apparently resistant to infections through the epidermis. When twig blighting occurs, it is largely confined to infections which enter through blighted blossoms, through attached mummies, or through various sorts of wounds which may appear upon the surface of the peach twig.

¹ Smith, Erwin F. Peach rot and peach blight. *Jour. of Mycology* 5: 123-134. 1889.

THE TROPICAL PLANT RESEARCH FOUNDATION

PERLEY SPAULDING

The Tropical Plant Research Foundation was incorporated under the laws of the District of Columbia, on June 6, 1924. The incorporators were Dr. Robert A. Harper, Maj. Geo. P. Ahern, and Dr. Wm. A. Orton. At a meeting of the incorporators the following trustees were elected to take charge of the affairs of the Foundation:

<i>Scientific men:</i>	<i>Years to Serve</i>	
<i>President</i> , Dr. L. R. Jones	2	Head of the Department of Plant Pathology of the University of Wisconsin. Representative of American Phytopathological Society.
<i>Vice-President</i> , Dr. R. A. Harper	3	Head of the Department of Botany of Columbia University. Representative of National Research Council.
Prof. S. C. Prescott	2	Head of the Department of Biology and Public Health, Massachusetts Institute of Technology.
Dr. D. L. Van Dine	1	Professor of Entomological Extension, Pennsylvania State College. Representative of American Association of Economic Entomologists.
Dr. William Crocker	1	Director, Boyce Thompson Institute for Plant Research, Yonkers, N. Y.
<i>Men representing business interests:</i>		
Mr. V. M. Cutter	5	Vice-President in charge of Tropical Divisions, United Fruit Company.
Mr. H. C. Lakin	4	President, The Cuba Company, New York.
Maj. Geo. P. Ahern	3	A retired army officer. Formerly, for fourteen years, Chief Forester of the Philippine Islands.
Mr. J. T. Crawley	1	Formerly Director of the Cuban Agricultural Experiment Station and of the Experiment Station of the Porto Rico Sugar Planters' Association. Now retired.

The articles of incorporation provide that the term of the organization shall be perpetual.

The particular objects and business of the Foundation are to promote research for the advancement of knowledge of the plants and crops of the tropics; to conduct investigations in plant pathology, entomology, plant

breeding, botany and forestry, horticulture and agronomy, and to publish the results thereof; and to establish and maintain such temporary or permanent stations and laboratories as may be necessary for the accomplishment of these objects, under the restrictions and regulations established in its by-laws.

The affairs, funds and property of the Foundation shall be in the general charge of a Board of Trustees, the number of whose members for the first year shall be nine, who shall be chosen by the incorporators, and who shall elect their successors, as provided for in the By-laws.

The By-laws of the Foundation provide that the members of the Board of Trustees will serve for five-year terms and will be eligible for re-election. Four members of the Board shall be representative of business interests, and five members shall be scientific men. Of the latter, one member shall be selected by the Board from nominees of the National Research Council; one from the membership of the American Phytopathological Society, after consultation with its Advisory Board; and one from the membership of the American Association of Economic Entomologists, after consultation with its Committee on Policy. The remaining six will be selected by the Board of Trustees as vacancies occur.

The Board will elect annually from its own members, a President and Vice-President; an Executive Committee of three to direct the affairs of the Foundation subject to the action of the Board, between meetings of the Board; a Treasurer; a Secretary; a Scientific Director and General Manager who must be a trained scientific man of established reputation and administrative ability, and who will have full charge of the work of the Foundation subject to the control of the Board of Trustees in matters of major policy; and an Executive Assistant, who will be charged with the business details of the work, direct the clerical force and act for the Scientific Director and General Manager during his absence.

A regular annual meeting of the Board of Trustees shall be held in the District of Columbia on the last Monday in April.

The National Research Council, the American Phytopathological Society, and the American Association of Economic Entomologists maintain advisory committees to advise the Foundation on the scientific phases of its projects and the choice of its scientific staff. This relation will be purely advisory.

The work of the Foundation is established upon a project basis and each must be approved by the Board of Trustees. The project statement will include the objects to be attained, the location of the work, the method of procedure which it is proposed to follow in the investigation, the leadership, relation to other agencies, cooperation if any, probable annual cost and source of support, and the estimated duration of the investigation.

Projects may be supported by individuals, firms, corporations, or other organizations. The administrative direction and control of the work shall be vested wholly in the Board of Trustees. Projects may be undertaken for states or governments under contracts approved by the Board of Trustees. The results of the research of the Foundation shall be published in the form of special reports or in scientific journals. The right to publish the scientific results shall not be waived or surrendered in any case.

The handling of the funds is safeguarded by their transmission through the Treasurer of the National Academy of Sciences and National Research Council, under proper audit by a certified public accountant.

Under the above terms the Board of Trustees have elected as Scientific Director and General Manager, Dr. William A. Orton, now Pathologist in charge of the Office of Cotton, Truck, and Forage Crop Disease Investigations of the Bureau of Plant Industry, United States Department of Agriculture.

The central office of the Foundation is in Washington, D. C. Address in care of the National Research Council. The northern laboratory headquarters will be at the Thompson Institute, Yonkers, N. Y. The tropical research will be done at temporary field laboratories located where the problems demand.

PHYTOPATHOLOGICAL NOTES

Photographic method for measuring and recording morphological and physical characters of plants. This method was devised as a means of describing types of sugar beets, used for breeding purposes. With this method one records easily and quickly data for innumerable exact measurements and characters, which may be referred to in the future as occasion requires. One not only obtains information for immediate use, but also records unconsciously much data, which often proves valuable in future years. This method shows to just what degree any individual approaches one's standard type. The complete record is in the form represented in figure 1, except that the corners marked off by dotted lines may be printed white as space for recording notes. It is hoped that this method will reduce the necessity for endless descriptions of degrees and characters, which are not always accurate.

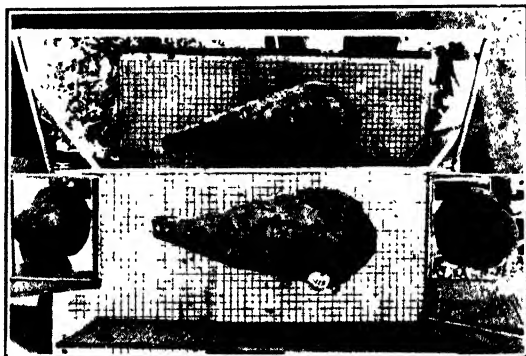


Fig. 1. Apparatus for photographing an object from four directions at one time.

The method consists in the photographing of beets against separate backgrounds of cross section paper. One centimeter cross section paper was used as a scale on these particular backgrounds although this could be varied to suit conditions. One background is placed horizontal and supports the beet directly below the camera lens, while the second background indicated by the number 2 in figure 1, is at a right angle to the first and is imaged in the large mirror at the opposite side of the apparatus. A mirror is then placed at each end of the horizontal background to give additional views. The mirrors are all held at different angles, depending upon the position of the camera lens. In our work we have placed the camera lens

exactly 120 centimeters from the horizontal background. This arrangement gives data for many measurements and four distinct views of the beet, with one exposure. The approximate angles of the mirrors and the supports for holding the beets in position are noted in figure 2.



Fig. 2. Showing angle of inclination of mirrors.

After this apparatus is set up, beets can be photographed very quickly. This apparatus has been used at this station during the past three years, and has given favorable results. With the suggestion of Dr. E. W. Brandes, Pathologist in Charge, Sugar Plant Investigations, the apparatus has been permanently mounted upon a base, as shown in figure 3. When not in use it folds up, and may be readily carried about.

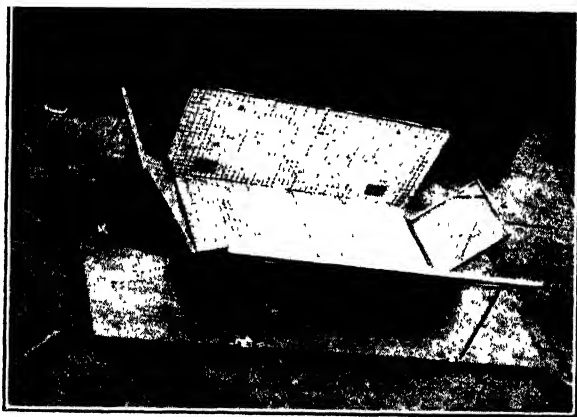


Fig. 3. Showing manner of fastening mirrors to base.

Since devising this apparatus the author finds that Havelock Ellis, in his book, *The Criminal*, 1915, illustrates a method of mirror photography.

Reference to this book shows that the position of the mirrors would prevent the use of scales and consequently no measurements could be made or recorded.—DEAN A. PACK.

Celery yellows.—Mr. Lowell F. Butler, who is working on celery yellows at the Colorado Agricultural College, reports the presence of two bacteria, one a short rod and the other a fusiform type, found in the brown internal lesions of the plants. He is now working to determine whether or not there may be a relation between the presence of these organisms and the occurrence of celery yellows.

Fusarium Conference, University of Wisconsin, Madison, Wis.—A general conference on the *Fusarium* problem held during June, July and part of August, at the University of Wisconsin, Madison, Wisconsin, has just come to a close. The conference developed out of studies carried on by the United Fruit Company on the wilt disease of bananas in Central America and was held in cooperation with the Bureau of Plant Industry, United States Department of Agriculture. Those present at the conference were Dr. H. W. Wollenweber, Pathologist, Biologische Reichsanstalt für Land und Forstwirtschaft, Germany, and Dr. O. A. Reinking, Pathologist, United Fruit Company, both representing the United Fruit Company; and Dr. C. D. Sherbakoff, Pathologist, Agricultural Experiment Station, University of Tennessee, Miss Helen Johann, Assistant Pathologist, Cereal Investigations, and Mrs. Alice Bailey, Junior Pathologist, Office of Cotton, Truck and Forage Crop Disease Investigations, representing the Bureau of Plant Industry, United States Department of Agriculture. The work of the conference covered, in so far as possible, the study, comparison and identification of specimens and cultures of fungi at present available. Because of the major part in the conference taken by the United Fruit Company, the main part of the studies were made on the tropical collection. The studies made of the entire collection embodied species from all sections of the sub-genus *Fusarium*, including important border-line strains, thereby making it possible to arrive at a uniform taxonomy of the group. It is believed that the principal points of difference have been agreed upon. A general paper presenting a clearer understanding of the *Fusarium* problem from the standpoint of the identification of species will be presented as a result of the studies. Pure cultures and dried specimens of each of the species studied and identified will be placed in the Office of Pathological Collections, Bureau of Plant Industry, United States Department of Agriculture.

Abstracts of papers for winter meeting.—November 1 is the time limit for the submission of abstracts of papers that are to be delivered at the

Washington Meeting. This is one month earlier than usual and members are asked to make special note of the change and to start preparation of their papers early. All abstracts will be reviewed and edited by an editorial committee and only those that embody definite results will be published.

—R. J. HASKELL, *Secretary-Treasurer*.

The August number of Phytopathology was issued August 20, 1924.

PHYTOPATHOLOGY

VOLUME XIV

NUMBER 10

OCTOBER, 1924

VARIETAL SUSCEPTIBILITY OF WHEAT TO *TILLETIA* *LAEVIS* KÜHN

GEORGE M. REED¹

The possibility of the utilization of bunt resistant varieties of wheat as a practical method of control of this disease has attracted the attention of several investigators. Among the hundreds of varieties of wheat which are known, some have been found which possess a marked resistance to bunt, although by far the larger number appear to be susceptible.

The bunt disease is coextensive with the culture of wheat and, in all the important wheat growing regions, is recognized as one of the most serious diseases of this crop. The disease may be caused by one of two closely related species of smuts, *Tilletia tritici* (Bjerk.) Winter and *T. laevis* Kühn. These two species are very similar in their general life history and in their pathological effects upon the host. They vary considerably in their distribution but frequently may be found in the same locality.

Farrer (6) was one of the first investigators to take up the study of the resistance of wheat varieties to bunt. He compared the susceptibility of ten Australian varieties and obtained infections varying from 12.0 to 95.5 per cent. Eight selections from plants of Allora spring wheat, which had escaped infection in the previous year, also were grown. All of these selections gave high infections—87.1 to 95.5 per cent.

Pye (29) compared twenty-one Australian varieties. One of these, Medeah, a Durum wheat, gave negative results. The others were infected to a greater or less extent; some of them quite severely. The varieties Genoa, Florence and Cedar gave the lowest percentages of infection.

McAlpine (20) compared several varieties and hybrids with reference to their susceptibility to *Tilletia laevis*. Federation, Medeah and hybrids of Bobs, Medeah and Tripola parentage, were quite susceptible. Ohio and Genoa proved to be resistant.

¹ Published by permission of the Director of the Agricultural Experiment Station of the University of Missouri.

Special acknowledgments are due to Fred N. Briggs, Jesse A. Cline, W. M. Gibbs, C. B. Hursh, Emma B. Mundy and C. A. Philpott for valuable assistance rendered in connection with these investigations.

In another report McAlpine (21) discusses more fully some of the results obtained in Australia. The varieties Genoa and Florence were grown at three different stations—Burnley, Dookie and Longerenong—and showed a fair degree of resistance. The average infection at the stations was 14.6 per cent for Genoa and 9.2 per cent for Florence. At Burnley, both *Tilletia tritici* and *T. laevis* were used but no important differences were observed. There also are reported the results with selections of a large number of crosses obtained by Pye at Dookie. Most of these showed high susceptibility but a few with Medeah parentage seemed to possess considerable resistance. A comparison of four varieties, Dexter, Federation, Florence and Genoa, with reference to their behavior to the two species of smut, was made. They responded in a very similar fashion to both.

Darnell-Smith (4) found that Cedar, Florence and Medeah were resistant to both *Tilletia laevis* and *T. tritici*. Comeback, Bobs and Federation gave 100 per cent infection with both species.

Von Tubeuf (39, 40) was one of the first investigators to report results from Europe. In 1900 he compared the behavior of eight varieties to *Tilletia tritici*, two of which, Ohio and Ontario, gave practically negative results and the remaining ones gave infections of 25.4 to 57.6 per cent. In 1901 the variety Ohio again gave practically negative results—Ontario not being grown. The other six varieties gave infections of 62.4 to 77.4 per cent. In this year, sixteen additional varieties also were tested; one, Bestehorns Ueberfluss, proved highly resistant and the others gave infections of 19.7 to 92.7 per cent. Von Tubeuf did not include the partially smutted plants in his data; otherwise his percentages of infection usually would have been higher.

Von Kirchner (16, 17, 18) has made the most extensive studies on the susceptibility of varieties of wheat to *Tilletia tritici*. Altogether he has studied 360 varieties or selections, of which 241 were winter wheats and 119 spring wheats. Most of these varieties belonged to *Triticum vulgare*, but the other species or races of wheat, *Triticum compactum*, *T. durum*, *T. dicoccum*, *T. monococcum*, *T. polonicum*, *T. spelta*, and *T. turgidum* were represented by one or more varieties. Many of the varieties were grown two or more years but in large part they were tested only one season. Further, von Kirchner generally recorded only the number of infected heads and did not give his results on the basis of the percentage of plants or heads infected. It also may be noted that great differences were observed in the amount of smut in a given variety in different years.

Von Kirchner found very marked variations in the susceptibility of the varieties. Only a few seemed to possess a high degree of resistance. It is especially interesting to note that one or more varieties of *Triticum compactum*, *T. turgidum*, *T. spelta*, *T. dicoccum*, and *T. vulgare* were very

susceptible. On the other hand, the varieties of *T. durum*, *T. polonicum*, and *T. monococcum* proved to be highly resistant to *Tilletia tritici*, although the infection of one or more varieties of each was obtained.

Malkoff (19) compared the susceptibility to *Tilletia laevis* of some Bulgarian wheats with that of introduced varieties and found that the former were much more susceptible. The Durum varieties were particularly attacked, giving infections of 70.5 to 88.3 per cent. Much lower infections were obtained in 1902-1903 than in 1903-1904.

Appel and Gassner (1) have mentioned that Ohio and Strubes Grannenweizen were highly resistant to *Tilletia tritici*.

Hecke (10) compared five spring wheats with five winter wheats for three seasons with reference to their behavior to *Tilletia tritici*. He found variations in the amount of infection in the different years but as a rule all ten varieties proved to be quite susceptible. On the whole, the highest infections were obtained with the winter varieties. In an experiment on the influence of the date of planting, he compared six varieties and observed great differences in the amount of smut. The variety Ohio, reported by von Tubeuf and Appel and Gassner as resistant, proved to be quite susceptible in Hecke's experiments.

Munerati (24, 25, 26, 27) in Italy has used a number of varieties in his experiments and usually has obtained high percentages of infection. The amount of smut, however, has varied greatly with the environmental conditions and the methods of inoculation. Peglion (28) in Italy compared fourteen strains of twelve varieties and obtained infections of 33.6 to 74.1 per cent. Strampelli (38) also compared fifteen varieties in Italy and obtained infections of 55.0 to 100 per cent. Schribaux (36), in France, found that Manitoba was quite resistant while four other varieties proved to be susceptible. Heuser (11), in his various experiments with *Tilletia tritici*, grew nine different varieties of wheat, all of which were quite susceptible. Various environmental factors were studied and their influence on infection was noted.

In Washington, Gaines (7, 8) inoculated thirteen varieties of wheat with *Tilletia tritici* and obtained percentages of infection from 18.6 to 96.4 per cent. The varieties Turkey and Alaska showed the greatest freedom from infection. In another experiment he obtained 3.4 per cent infection of Turkey, 5.8 per cent of Florence and 70.9 per cent of Hybrid 128. The second and third generations of the cross between Turkey and Hybrid 128 gave infections varying from those comparable to the Turkey variety to others as high as those usually obtained with Hybrid 128. A cross between Turkey and Florence, two resistant varieties, also was studied. Some of the second and third generation families gave much higher infections than either parent.

Stephens and Woolman (37) have recorded their observations on the resistance of a large number of wheat varieties in Oregon to *Tilletia tritici*. Most varieties proved to be highly susceptible, but three, Martin Amber, White Odessa and Red Hussar, showed marked resistance. A large number of selections of Crimean wheats also gave low percentages of infection. No striking cases of resistance were observed among eighty-five Australian and 120 Indian wheats which were grown. Selections from crosses between Turkey and Florence were notably resistant.

Coons (3) has reported some results with *Tilletia laevis* on forty varieties of wheat. Most of these were susceptible, infections of 20 to 66 per cent being obtained. A few varieties, however, showed resistance. These were mainly Turkey or selections from crosses of this type, although one strain of Fultz also is recorded as resistant. Johnston (14) has noted briefly some results in Kansas. He found that hard winter wheats of the Turkey type were resistant to both *Tilletia laevis* and *T. tritici* and that the soft winter varieties were more susceptible to *T. tritici* than to *T. laevis*. The average of twenty varieties of soft winter wheats gave 3.4 per cent infection with *T. laevis* and 25.1 per cent with *T. tritici*.

METHODS AND RESULTS

In the autumn of 1913 the writer began his studies at Columbia, Mo., on the varietal resistance of winter wheats to *Tilletia laevis*. Brief reports (30, 31, 32, 33, 34) on the progress of these experiments have appeared. The present paper is a final statement of the results which were obtained.

The material of *Tilletia laevis* was obtained from a crop of badly infected wheat grown in the vicinity of Columbia. The varieties and selections of winter wheats used were secured from the Department of Farm Crops of the University of Missouri.

On October 2, 1913, the seed of forty varieties of common wheats of Missouri, inoculated with the spores of *Tilletia laevis*, were sown. Practically all of these varieties gave negative results. A few, however, gave very low percentages of infection. Sixty selections from several varieties of common winter wheats also were inoculated. Most of these were sown on October 25 and the remaining ones on November 4. The results are given in table 1.

The chief point of interest in these results with the selections lies in the very high percentages of infection which were secured. By far the larger number gave more than 50 per cent of infected plants and in several the percentage was above 90. These results are in striking contrast to those obtained with the varieties which were sown on the earlier date.

The second point of interest is that no striking cases of resistance were observed. There were differences in the susceptibility of the various selec-

TABLE 1.—*Susceptibility of winter wheat selections to Tilletia laevis Kuhn, 1913-1914*

Selection	Total No. of Plants	No. Inf.	Per cent Inf.	Selection	Total No. of Plants	No. Inf.	Per cent Inf.
1	68	56	82.3	43	66	51	81.6
3	91	71	78.0	47	62	51	82.2
4 (X)	90	57	63.3	48	59	50	84.7
4	83	76	91.5	49*	87	68	78.1
5	40	28	70.0	51*	79	40	50.6
7	83	24	28.9	52	80	16	20.0
9	80	57	71.2	53	53	43	81.1
10	60	45	75.0	56*	85	83	97.6
11	78	60	76.9	59	42	34	80.9
12	70	48	68.5	60	49	34	69.3
15	67	62	92.5	61*	61	48	78.6
18 D-4	62	51	82.2	63	48	35	72.9
19	107	96	89.7	64	61	56	87.5
20	62	56	90.3	66*	66	56	84.8
24	77	52	67.5	67	49	33	67.3
25 A-1-5	68	62	91.1	73*	41	25	60.9
26	72	64	88.8	75*	67	58	86.5
28 B-1	74	71	95.9	81	67	58	86.5
28 B-2	74	31	41.8	83*	68	58	85.2
29	80	64	80.0	86	59	51	86.4
29 C-2	58	31	53.4	93	51	30	58.8
30	65	54	83.0	95*	60	36	60.0
32	52	35	67.3	97*	68	46	67.6
33 A-3*	71	56	78.8	98	67	58	86.5
33 A-4	95	74	77.8	101	66	54	81.8
34	46	39	84.7	195	60	57	95.0
35	79	72	91.1	215	45	38	84.4
35 C-1-8	56	44	78.5	245	77	62	80.5
37 (X)	48	33	68.7	247	69	58	84.0
37	65	29	44.6	Black winter Emmer	53	6	11.3
37 A-1	79	71	89.8				
41	70	56	80.0				

* Seed sown Oct. 25, 1913, except the starred numbers which were sown Nov. 4.

tions but none showed any marked degree of resistance to *Tilletia laevis*. Black Winter Emmer, a variety of *Triticum dicoccum*, gave 11.3 per cent infection. All the other selections belonged to *Triticum vulgare*.

Another experiment was carried out in 1913 in which separate lots of seed of three varieties were inoculated with spores of *Tilletia laevis* taken from the same varieties. These results are given in table 2.

TABLE 2.—*Influence of source of spores of Tilletia laevis Kuhn, 1913-1914*

Source of Spores	Early Ripe			Red Cross			Treadwell		
	Total No. of Plants	No. Inf.	Per cent Inf.	Total No. of Plants	No. Inf.	Per cent Inf.	Total No. of Plants	No. Inf.	Per cent Inf.
Early Ripe*	191	144	75.3	177	133	75.1	171	111	64.9
Early Ripe**	270	176	65.1	227	168	74.0	229	109	47.5
Red Cross*	193	145	75.1	160	128	80.0	185	87	47.0
Treadwell*	180	158	87.7	196	168	85.7	158	107	67.7

* Seed sown October 14, 1913.

** Seed sown November 4, 1914.

No important differences in the infections by the different spore lots were observed, although the spores from the variety Treadwell gave somewhat higher results on all three varieties. The variety Treadwell was consistently less infected than the other two varieties, the percentage of infection varying from 47 to 67.7 per cent. Early Ripe gave infections of 65.1 to 87.7 per cent and Red Cross, infections of 74 to 85.7 per cent. There were two sowings of Early Ripe inoculated with spores from the same variety. The sowing on November 4 gave slightly lower percentages of infection than that of October 14.

In 1914 seven varieties were inoculated and planted on October 28. The results are given in table 3.

TABLE 3.—*Susceptibility of winter wheat varieties to Tilletia laevis Kuhn, 1914-1915*

Variety	Total No. of Plants	Number Infected	Per cent Infected
Early Ripe	96	9	9.3
Fultz	121	12	9.9
Harvest Queen	331	168	50.7
Mealy	71	3	4.2
Mediterranean	84	5	5.9
Poole	58	8	13.7
Rural New Yorker	45	2	4.4

Seed sown October 28, 1914.

In general, very low percentages of infection were obtained. The variety Harvest Queen, however, gave 50.7 per cent infection.

In 1915, fifteen varieties were inoculated. One lot of seed of five of these varieties was sown on October 2 and a second lot of seed on October 30.

Seed of seven additional varieties was sown on October 21 and a second lot on October 30. The remaining three varieties were sown on October 30. The results are given in table 4.

TABLE 4.—*Susceptibility of winter wheat varieties to Tilletia laevis Kuhn, 1915-1916*

Variety	Seed sown Oct. 2, 1915			Seed sown Oct. 21, 1915			Seed sown Oct. 30, 1915		
	Total No. of Plants	No. Inf.	Per cent Inf.	Total No. of Plants	No. Inf.	Per cent Inf.	Total No. of Plants	No. Inf.	Per cent Inf.
Defiance	96	8	8.3				159	61	38.3
Early Ripe	87	27	31.0				210	105	50.0
Fuleaster	77	37	48.0				172	108	62.8
Fultz				164	85	51.8	198	86	43.4
Harvest King				146	34	23.9	170	50	28.5
Harvest Queen							306	182	59.4
Lebanon				181	83	45.8	256	130	50.7
Mealy							143	71	49.6
Mediterranean				157	72	45.8	175	71	40.5
Michigan Wonder				161	36	22.3	222	67	31.8
Poole				131	71	53.4	195	101	51.7
Rural New Yorker							173	73	42.2
Treadwell				174	47	27.0	232	92	39.9
Turkey	71	12	16.9				262	92	35.1
Velvet Chaff	74	12	16.2				137	60	43.8

The five varieties sown on October 2 and again on October 30 gave much higher percentages of infection in the later planting as compared with the early. The range of infections of the first planting was 8.3 to 48 per cent and in the second 35.1 to 62.8 per cent. There was no marked difference in the infection of the sowings made October 21 as compared with October 30. All fifteen varieties, however, gave quite high percentages of infection.

In 1916, seventeen varieties were grown. Separate lots of seed were sown on September 23, October 10 and November 3. These results are given in table 5.

In every case the infections were unusually low. While none of the varieties gave entirely negative results, the highest percentage of infection obtained with any variety on any date was 6.7 per cent. No important differences are observable in the seedlings of the different dates.

In 1917 about thirty varieties were grown and all the varieties proved to be susceptible, the percentages of infection varying from 5 to 80 per cent.

TABLE 5.—*Susceptibility of winter wheat varieties to Tilletia laevis Kühn, 1916–1917*

Variety	Date of Planting								
	Sept. 23, 1916			Oct. 10, 1916			Nov. 3, 1916		
	Total No. of Plants	No. Inf.	Per cent Inf.	Total No. of Plants	No. Inf.	Per cent Inf.	Total No. of Plants	No. Inf.	Per cent Inf.
Beechwood Hybrid	262	16	6.1	114	4	3.5	89	3	3.3
Defiance	349	6	1.7	481	8	1.6	337	3	.8
Dietz	329	6	1.8	204	5	2.4	178	3	1.6
Early Ripe	270	11	4.0	142	6	4.2	86	2	2.3
Fulcaster	264	3	1.1	159	3	1.8	204	5	2.4
Fultz	242	7	2.8	123	6	4.8	195	5	2.5
Harvest King	339	11	3.2	130	6	4.6	94	4	4.2
Harvest Queen	172	4	2.3	339	5	1.4	218	3	1.3
Lebanon	281	10	3.5	114	1	.8	150	4	2.6
Mealy	257	2	.7	110	1	.9	56	1	1.7
Mediterranean	140	4	2.8	92	4	4.3	110	3	2.7
Michigan Wonder	263	17	6.4	173	11	6.3	141	7	4.9
Poole	170	8	4.7	86	4	4.6	83	3	3.6
Rural New Yorker	49	1	2.0	115	1	.8	75	1	1.3
Treadwell	298	10	3.3	117	3	2.5	185	4	2.1
Turkey	190	12	6.3	344	16	4.6	458	31	6.7
Velvet Chaff	268	3	1.1	193	1	.5	142	1	.7

DISCUSSION

The more commonly grown varieties of winter wheats of Missouri were used in the course of these experiments and all proved to be quite markedly susceptible to *Tilletia laevis* Kühn. In at least one or more seasons a large percentage of infected plants was secured and in some years the number infected was very large. This was particularly true of the sowings with certain varieties in 1913 and in 1915. There was, however, very great variation in the percentages of infection obtained in the different years. In 1913 and 1915 a high percentage of infection was secured; on the other hand, the results were low in 1914 and 1916.

In 1913 and in 1915 great variation occurred in the amount of smut depending upon the date of seeding. In 1913, varieties sown on October 2, gave practically negative results, while the selections sown on October 25 and November 4, gave exceptionally high infections—in many cases over 90 per cent. In the experiment in which the spores from different varieties were used, it was found that the sowing of the variety Early Ripe, of October 14, gave a larger percentage of infected plants than the sowing of November 4. In 1915 the percentages of infection of five varieties sown on

October 2, were 16 to 30 per cent lower than on the same varieties sown on October 30. On the other hand, there were no obvious differences in the amount of smut on the varieties sown on October 21, and again on October 30. The three sowings of 1916 were about three weeks apart but no obvious differences appear in the results for the different dates.

A large number of observations have been made on the relation between the date of planting and the prevalence of bunt of wheat. Kellerman and Swingle (15) and Munerati (24, 25) found that late sowing of winter wheats in the autumn resulted in a more severe infection of bunt than early spring sowing. Hecke (10), Munerati (24, 25), Schribaux (36), Müller and Molz (22) and Heuser (11) obtained higher infections in the early sown spring wheats than in the later, while Müller, Molz and Morgenthaler (23) found no definite correspondence between the date of sowing and the amount of bunt. Volkart (41) found more bunt (63.7 per cent) in winter wheat sown early in the autumn than when sown later (39.3 per cent) and Müller and Molz (22) also obtained similar results. Appl (2) and Heuser (11) found that when a series of sowings of wheat inoculated with the spores of *Tilletia tritici* was made in the autumn, the most severe infections occurred neither in the very early nor the very late seeding. The same observations were made by Heald (9) and Schafer, Gaines and Barbee (35) with *Tilletia tritici* in eastern Washington. The situation there, however, is complicated by the fact that soil infestation is known to occur. Malkoff (19) found no important differences in the amount of *Tilletia laevis* in wheat sown on four different dates from October 10 to November 10.

Several investigators have endeavored to determine the relation of moisture, temperature and other soil factors to the infection of wheat by bunt. Von Tubeuf (39) obtained 55.3 per cent infection by *Tilletia tritici* in wheat planted in sandy soil and watered as compared with 29.3 per cent infection of plants in similar soil but not watered. Volkart (41) accounts for the greater infection of wheat by *Tilletia tritici* in his early planting as compared with the later on the basis of a soil moisture more favorable for the rapid germination of the wheat. Appl (2) concluded that the small differences in the temperature ranges were not sufficient to explain his results with *T. tritici*. From his examination of the records on the amount of precipitation during the period of germination he concluded that soil moisture is of greater importance than temperature for successful infection. Hungerford (12) also concluded that moisture is particularly important in the infection of wheat by *T. tritici* in Idaho where soil infestation occurs.

As regards *Tilletia laevis*, Ivanoff (13) suggests the importance of soil moisture. Malkoff (19) also found different amounts of smut in several varieties of wheat in two successive years. His analysis of the meteorological conditions led him to conclude that the amount of moisture in the soil

during the germination period of the seed had a very marked effect upon the extent of the subsequent infection.

Iiecke (10) attempted to correlate the amount of *Tilletia tritici* in spring wheat with the temperature conditions. The highest percentages of infection were obtained in the early sowings although some rather marked exceptions occurred. In general Iiecke found that with low temperatures there was a higher percentage of infection. Munerati (26) obtained 1.4–12 per cent infection in four varieties of wheat germinated at 18–20° C. These same varieties germinated at 7–8° C. gave 92–100 per cent infection. More recently Munerati (27) has reported some additional results on the temperature relations of the infection of wheat. He used two varieties, Gentile Rosso and Cologna, and obtained the following results: Seed germinated at 22–25° C. gave 0–1.4 per cent infection; germinated at 10–12° C. gave 13.2–39.3 per cent; germinated at 2–4° C. for forty days gave 0–1.9 per cent; germinated at 2–4° C. for twenty days, then at 22–25° C. gave no infection; germinated at 2–4° C. for twenty days, then at 10–12° C. for seven days and finally at 22–25° C. gave 19.7–24.4 per cent. Heuser (11) secured 1.8–6 per cent infection in three varieties germinated at 16–22° C. and 66.2–94.7 per cent in the same varieties germinated at 6–10° C.

As already emphasized, my own results varied widely in the different years and in the seedlings made on different dates. It does not seem possible to definitely correlate these results with any specific temperature or moisture conditions. The air temperature before and after the seeding dates, together with the amount of precipitation for the different years, is recorded in table 6. The data given for the period after seeding varies in the number of days, since the time required for the seedlings to emerge from the soil depends somewhat upon the temperature.

Following the first sowing of 1913 the temperature was above 20° C. and very little rain fell. Practically all of the varieties sown gave negative results. The temperature following the remaining three seedings of 1913 varied from 6–10° C. and in every case a considerable amount of rain fell during the germination period. Quite high percentages of infection were obtained. These results suggest that the low temperature, combined with the moisture, was particularly favorable for infection. In 1914 the temperature was about 13–14° C. during the germination period and no precipitation occurred. The results were comparatively low although 50 per cent of bunt was secured in the variety Harvest Queen. In 1915 the average temperature during the first period of germination was 13–14° C. and during the second period was about 15–16° C. and during the third period was about 17° C. Notably higher percentages of infection were obtained from the second and third sowing. No rain fell during the second and third periods of germination. In 1916 the average temperature during

TABLE 6—*Temperature and precipitation during the period of seeding of winter wheat at Columbia, Mo., 1913-1916*

Date	10 days Before sowing		After sowing		
	Average Temp.	Total Precip.	No. of Days	Average Temp.	Total Precip.
Oct. 2, 1913	15° C.	.74	6	20.5° C.	.05
Oct. 14, 1913	20° C.	.34	15	9.0° C.	2.04
Oct. 25, 1913	8° C.	1.50	20	6.7° C.	.81
Nov. 4, 1913	5° C.	.56	15	8.5° C.	2.20
Oct. 28, 1914	14° C.	.01	10	13.5° C.	0.0
Oct. 2, 1915	18° C.	.02	12	13.0° C.	.89
Oct. 21, 1915	16° C.	1.11	10	15.5° C.	0.0
Oct. 30, 1915	15° C.	0.0	9	17.0° C.	0.0
Sept. 23, 1916	15° C.	.33	10	16.0° C.	1.99
Oct. 10, 1916	20° C.	T	13	11.0° C.	1.21
Nov. 3, 1916	13° C.	.34	10	13.5° C.	1.28

all three periods of germination was 11–16° C. and relatively high precipitation occurred. In every case, low percentages of infection were secured although the temperatures were certainly favorable, since in previous years under similar temperature conditions a large amount of smut was secured. It is possible that the temperature was too high for favorable infections in the first sowing of 1913 but it seems evident that the temperatures were favorable in the other years.

So far as precipitation is concerned the amount was very much greater in 1913 and 1916 as compared with either 1914 or 1915. In 1913, a year of relatively high precipitation and fairly low temperature, a large percentage of infection occurred. On the other hand, in 1915 at a considerably higher temperature and no precipitation, high infections also were secured.

It seems evident that soil moisture, soil temperature and other possible soil conditions are interdependent factors which determine the occurrence of bunt in wheat. Their interaction determines whether infection will take place and also the severity of the attack. Any one of these factors may be a limiting one in the prevention of infection.

Data have been reported on the relative susceptibility of different varieties of wheat to *Tilletia laevis* and *T. tritici*. Von Kirchner (18) used *T. tritici* in his experiments and found that varieties of *Triticum durum* were comparatively resistant. Malkoff (19) used *T. laevis* and found that durum varieties of wheat were very much more susceptible than varieties of *Triticum vulgare*. McAlpine (21) and Darnell-Smith (4) in Australia

found no obvious differences in the susceptibility of some Australian wheats to the two species of *Tilletia*. Stephens and Woolman (37) compared the behavior of eight varieties to the two species and found no noteworthy differences. Johnston (14) obtained very low infections of the soft winter wheats by *T. laevis*, while higher infections were obtained with *T. tritici*. His results with *T. laevis* are surprising in view of the comparatively high infections obtained by Coons (3) as well as the results reported by the writer.

Various investigators have obtained different results with certain varieties. The Australian investigators in general have reported that Medeah was resistant. McAlpine (20), however, obtained as high as 46.6 per cent infection of this variety by *Tilletia laevis*. Von Tubeuf (39, 40), Appel and Gassner (1) and von Kirchner (18) have emphasized the resistance of the variety Ohio. Hecke (10), however, obtained 61.9 per cent infection of this variety. It is quite probable in the light of the results recently reported by Faris (5) with the covered smut of barley that specialized races of species of *Tilletia* also may occur and the discrepancies recorded by the different observers may in part be explained upon this basis. Further investigations along this line are particularly important.

It is obvious that experiments to determine the resistance of plants to particular diseases must be repeated over a series of years. If positive results are obtained, evidence is at once secured as to the susceptibility of the variety but negative results or low percentages of infection are not definite criteria as to the resistance of the variety in question. One might conclude from the 1916 results that all the soft winter wheats tested possess a high degree of resistance. As a matter of fact, the records for the years 1913 and 1915 show clearly that they are highly susceptible. If one could assure appropriate conditions for high infection in any given season, then one test might serve to determine the resistance of a variety. Since this can not be done under field conditions, conclusions based on the results of one season can not be accepted as final and the determination of the behavior of the variety over a series of years is essential.

LITERATURE CITED

1. APPEL, O., and G. GASSNER. Untersuchungen über den Brand, insbesondere den Flugbrand des Getreides. Mitteil. Kaiserlichen Biol. Anstalt für Land- und Forstwirtschaft. 4: 9-12. Fig. 2-3. 1907.
2. APPEL, JOH. Saatzeit und Steinbrandbefall des Weizens. Zeitschr. f. d. Land. Versuchswesen Oesterreich 18: 45-54. 1915.
3. COONS, G. H. Varietal resistance of winter wheats to *Tilletia laevis*. Phytopath. 14: 38, 39. 1924.
4. DARNELL-SMITH, G. P. Some observations on bunt and fungicides. Agric. Gaz. New South Wales 21: 751-756. 4 fig. 1910.

5. FARIS, J. A. Factors influencing infection of *Hordeum sativum* by *Ustilago hordei*. Amer. Jour. Bot. 11: 189-214. Pl. 7-8, 7 fig. 1924.
6. FAIRAR, W. Results of the Lambrigg bunt experiments of 1900. Agric. Gaz. New South Wales 12: 419-430. 1901.
7. GAINES, E. F. Comparative smut resistance of Washington wheats. Jour. Amer. Soc. Agron. 10: 218-222. 1918.
8. ———. The inheritance of resistance to bunt or stinking smut of wheat. Jour. Amer. Soc. Agron. 12: 124-132. 1920.
9. HEALD, F. D. The stinking smut of wheat. Washington Agric. Exp. Sta. Pop. Bull. 115. 14 p., 1 fig. 1918.
10. HECKE, L. Der Einfluss von Sorte und Temperatur auf den Steinbrandbefall. Zeitsch. für das Landwirtsch. Versuch. Oesterreich 12: 49-66. 1909.
11. HEUSER, W. Versuch über den Einfluss äusserer Bedingungen auf die Stärke des Steinbrandbefalles des Weizens. Fühl. Land. Zeit. 71: 81-99. 1922.
12. HUNGERFORD, C. W. The relation of soil moisture and soil temperature to bunt infection in wheat. Phytopath. 12: 337-352. 5 fig. 1922.
13. IVANOFF, K. S. Phytopathologisches aus Transkaukasien. Zeitschr. Pflanzenkr. 13: 221-222. 1903.
14. JOHNSTON, C. O. Wheat bunt investigations in Kansas. Phytopath. 14: 37. 1924.
15. KELLERMAN, W. A., and W. T. SWINGLE. Preliminary experiments with fungicides for stinking smut of wheat. Kansas Agric. Exp. Sta. Bull. 12: 25-51. Pl. 1. 1890.
16. KIRCHNER, OSCAR. Über die Empfänglichkeit verschiedener Weizensorten für die Steinbrand-krankheit. Fühl. Landw. Zeit. 55: 781-794. 1906.
17. ———. Neue Beobachtungen über die Empfänglichkeit verschiedener Weizensorten für die Steinbrand-krankheit. Fühl. Landw. Zeit. 57: 161-170. 1908.
18. ———. Untersuchungen über die Empfänglichkeit unserer Getreide für Brand-und-Rostkrankheiten. Fühl. Landw. Zeit. 65: 1-27, 41-72, 92-137. 1916.
19. MALKOFF, KONSTANTIN. Untersuchungen über verschiedene Pflanzenkrankheiten. Arb. Staatl. Landw. Versuchsst. Sadovo, Bulgarien, No. 2. 54 p., 16 pl. (partly col.). 1907.
20. McALPINE, DANIEL. Rust and smut resistance in wheat and smut experiments with oats and maize. Jour. Dept. Agric. Victoria 8: 284-289. 1910.
21. ———. The smuts of Australia, their structure, life history, treatment, and classification. P. VII + 288. Illus. 1910.
22. MÜLLER, H. C., and MOLZ, E. Über den Steinbrand des Weizens. Fühl. Landw. Zeit. 63: 204-214. 1914.
23. MÜLLER, H. C., MOLZ, E., and O. MORGENTHALER. Über Brandbekämpfung und den Einfluss der Bestellzeit beim Sommerweizen auf dessen Ertrag und Gesundheit. Die Landwirtschaft. Versuchss. 83: 211-220. 1913.
24. MUNERATI, O. La recettività del frumento per la carie in rapporto col tempo di semina. Rend. Classe Sci. Fis., Mat. Nat. Accad. Lincei, serie 5, 20: 835-840. 1911.
25. ———. Sulla recettività del frumento per la carie in rapporto al tempo di semina. Rend. Cl. Sci. Fis., Mat. Nat. Accad. Lincei, serie 5, 21: 875-878. 1912.
26. ———. Osservazioni sulla recettività del frumento per la carie. Rend. Cl. Sci. Fis., Mat. Nat. Accad. Lincei, serie 5, 31: 125-129. 1922.

27. —————. Le basse temperature al momento della germinazione fanno sfuggire il grano all'attacco della carie? Rend. Cl. Sci. Fis., Mat. Nat. Accad. Lincei, serie 5, 32: 285-289. 1923.
28. PEGLION, VITTORIO. Intorno al comportamento di alcune varietà di frumento rispetto alla carie. Rend. Cl. Sci. Fis., Mat. Nat. Accad. Lincei, serie 5, 28²: 398-400. 1919.
29. PYE, H. Diseases and pests of cereals. Jour. Dept. Agric. Victoria 7: 368-373. 1909.
30. REED, G. M. Grain smut infections and control. Missouri Agric. Exp. Sta. Bull. 131: 469. 1915.
31. —————. Grain smut investigations and control. Missouri Agric. Exp. Sta. Bull. 147: 27, 28. 1917.
32. —————. Grain smut investigation and control. Missouri Agric. Exp. Sta. Bull. 151: 32, 33. 1917.
33. —————, E. B. MUNDY and N. M. GIBBS. Grain smut investigation and control. Missouri Agric. Exp. Sta. Bull. 141: 26. 1916.
34. —————, C. A. PHILPOT and J. A. CLINE. Grain smut investigation and control. Missouri Agric. Exp. Sta. Bull. 163: 31-33. 1919.
35. SCHAFER, E. G., E. F. GAINES and O. E. BARBEE. Wheat production as influenced by variety, time of seeding and source of seed. Washington Agric. Exp. Sta. Bull. 159. 34 p. 1921.
36. SCHIRBAUX, NIVOIT. Resistance du Manitoba aux maladies cryptogamiques. Compt. Rend. Cl. Sci. Fis., Mat. Nat. Accad. Lincei, 28²: 151-153. 1919.
37. STEPIENS, D. E., and H. M. WOOLMAN. The wheat bunt problem in Oregon. Oregon Agric. Exp. Sta. 188. 42 p. illus. 1922.
38. STRAMPPELLI, NAZARENO. Esperienze intorno alla carie (*Tilletia caries*) del frumento. Rend. Cl. Sci. Fis., Mat. Nat. Accad. Lincei, 28²: 151-153. 1919.
39. TUBEUF, CARL VON. Studien über die Brandkrankheiten des Getreides und ihre Bekämpfung. Arbeit. Biol. Abt. K. Gesundheits. 2: 179-349. Pl. 8. 1901-02.
40. —————. Weitere Beiträge zur Kenntniss der Brandkrankheiten des Getreides und ihrer Bekämpfung. Arbeit. Biol. Abt. K. Gesundheits. 2: 437-467. 1902.
41. VOLKART, U. Die Bekämpfung des Steinbrandes des Weizens und des Kornes. Landw. Jahrb. Schweiz 20: 445-490. illus. 1906.

BACTERIAL SOFT-ROT OF TOMATO

S. A. WINGARD¹

WITH THREE FIGURES IN THE TEXT

A bacterial soft-rot of tomato fruits is of general occurrence in Virginia and is a factor of considerable economic importance. It is the most common fruit rot in the state and probably causes greater losses on the average than any of the other fruit rots of tomato. The writer's attention was first attracted to the disease during the summer of 1918 when it appeared in destructive form in a series of tomato plats on the experiment station farm at Blacksburg. These plats were sprayed for the control of *Septoria* leaf-blight and they afforded splendid opportunity for the study of soft-rot.



FIG. 1. Tomato fruit 6 days after inoculation with *B. aroidae*. Note the check punctures on either side of the decayed region.

The field studies were supplemented by investigations in the laboratory and greenhouse during the fall and winter months and also during the following year. The results of these studies are briefly described in this paper.

So far as the writer is aware there has been no extended study of the fruit rot in question and practically no information is available in published form. Earle (1) described a bacterial soft-rot of tomato in Alabama in 1900 which he reported as being very destructive. He isolated the bac-

¹ Paper No. 62 from the Department of Plant Pathology, Virginia Agricultural Experiment Station.

terium and proved its pathogenicity by inoculating tomato fruits with pure culture; however, the identity of this organism was not determined. Humbert (3) in 1918 reported a tomato fruit rot as occurring in Ohio. This author referred to the disease as "leak" and stated that bacteria were found associated with it. Sherbakoff (6) referred to tomato soft-rot in a



FIG. 2. Tomato fruits 8 days after inoculation with *B. aroideae*. Note the exudate on the bottom of each.

paper on Florida tomato diseases in 1918, and stated that it was of considerable economic importance in some cases.

DESCRIPTION OF THE DISEASE

Tomato soft-rot is strictly a fruit rot to which the green fruit is especially susceptible. Ripe fruit is not so seriously affected unless infection is initiated while it is still green.

The first indication of infection is the appearance of a water-soaked area on the surface of the fruit (Figure 1). The affected area is depressed with a sharp margin of sound tissue. The tissue within the affected region becomes opaque in a short time, but there is always a narrow band of water-soaked tissue near the margin. The affected region becomes very much wrinkled and often cracks. The entire fruit is converted into a soft, watery, colorless, decayed mass within a period of three to ten days (Figure 2).



FIG. 3. Tomato fruits 12 days after inoculation with *B. aroideae*. The fruit on the left has burst and "leaked" its contents.

The completely rotted fruits often burst and "spill" their contents as shown in Figure 3. This decay is accompanied by offensive odors.

CAUSAL ORGANISM

The soft-rot organism was readily isolated from the affected tomato fruits on beef-peptone agar. Glistening, grayish-white colonies, which later proved to be those of the soft-rot organism, appeared on this media after a period of 24 hours. A detailed study of the organism was under-

taken by A. B. Massey² who has shown that it is referable to *Bacillus aroideae* Townsend³. Townsend (7) in 1904 demonstrated that this organism was capable of rotting tomato fruits and certain other vegetables besides causing a rot of the calla lily.

Although the organism in question was found to be *Bacillus aroideae*, it is known that some other organisms are capable of producing similar rots of tomato fruits. Jones (4) in 1900 found that *Bacillus carotovorus* is capable of producing a soft-rot when inoculated into tomato fruits. Pritchard and Porte (5) have shown that a form of *Oospora lactis* produces a watery-rot of tomato fruits which occurs most commonly in shipments of southern grown tomatoes.

PATHOGENICITY

Preliminary inoculations were made on twelve green tomato fruits growing on plants in the greenhouse. These fruits were swabbed with a 1-1000 solution of mercuric chloride and then punctured with the point of a sterile needle which had been previously dipped into a pure culture of the soft-rot organism. Similar green fruits were disinfected and punctured with a sterile needle as controls. Within 24 hours, each of the needle punctures on the inoculated fruits was surrounded by a water-soaked area about 1 cm. in diameter. The decayed spots thus produced were similar in every respect to those which occurred on the fruits in the field. A week later all of the inoculated fruits had been completely transformed into soft-watery masses. The controls remained sound and ripened without any apparent injury. The soft-rot organism was readily reisolated from the inoculated fruits.

In another test, green tomato fruits, which were from 1 to 1.5 inches in diameter, were inoculated by needle puncture and all of them were completely decayed in 11 days.

Another lot of green fruits which ranged in diameter from 1 to 2.5 inches were inoculated in a similar manner. Two of these showed complete decay in 9 days, and four in 12 days. Three others were half rotted in 12 days.

METHOD OF INFECTION

In order to determine whether the soft-rot organism can infect through the unwounded epidermis, green tomato fruits on plants growing in the greenhouse bed were smeared with the organism from pure culture. Other

² See A study of *Bacillus aroideae* Townsend, the cause of a soft-rot of tomato, by A. B. Massey in this issue of Phytopathology.

³ According to the newer classification recommended by the Society of American Bacteriologists the name of this organism becomes *Erwinia aroidea* (Townsend) Comm. S. A. B.

fruits were punctured with a sterile needle and then smeared with a pure culture of the soft-rot organism, and others were punctured and held as controls. The fruits were about one-half mature size. These inoculations were made in the late afternoon in order to allow the organism to remain over night before being exposed to the sun. The results of this experiment are given in table 1.

No infection resulted on any of the unwounded fruits in this experiment, while all of those which were wounded before inoculation showed complete decay within 12 days.

A similar test was made with green fruits removed from the plants and placed in moist chambers at a temperature of 30° C. The fruits which were punctured and inoculated were completely decayed within 7 days, whereas the controls and those which were inoculated without wounding remained sound. The contents of the decayed fruits "leaked" and covered the bottom of the moist chamber to a depth of 5 mm. yet the unwounded fruits, which lay in this bacterial suspension for several days, did not become infected.

TABLE 1.—*Results of inoculation with Bacillus aroideae made on green tomato fruits, on March 3, 1919*

Method of inoculation	Number of fruit	Diameter of decayed spot in cm.	
		March 5	March 12
Organism smeared on punctured surface	1	7	complete decay
	2	9	" "
	3	7	" "
	4	5	" "
	5	5	" "
	6	7	" "
	7	7	" "
Organism smeared on unwounded surface	1	no infection	no infection
	2	" "	" "
	3	" "	" "
	4	" "	" "
	5	" "	" "
	6	" "	" "
	7	" "	" "
	8	" "	" "
Controls, punctured with sterile needle	1	no infection	no infection
	2	" "	" "
	3	" "	" "
	4	" "	" "
	5	" "	" "

Another set of inoculations was made in the greenhouse on 24 fruits of the Norton and Marvel varieties by applying pieces of decayed fruits to their unpunctured surfaces. Within 48 hours, five of these fruits had decayed spots at the stem-end, and one was beginning to decay along a groove

on the side. Within 10 days, fourteen of these fruits were completely decayed, one was partially decayed, and the others remained unaffected. Infection had taken place through the stem ends of twelve fruits, through the blossom ends of two, and through a growth crack in the side of one. It is common to find cracks at the stem and blossom ends of tomato fruits in the greenhouse and it is probable that infection resulted through such cracks. There was no evidence to indicate that the organism had gained entrance through the uninjured skin.

Observations in the field have shown that soft-rot infection takes place through growth cracks, sun scalds and insect injuries.

SUSCEPTIBILITY OF VARIETIES

In order to compare the susceptibility of different varieties to soft-rot, ten fruits of each of the following were inoculated in the greenhouse by needle puncture: Norton, Marvel, Royal Red, Burbank, Red Cherry, and Yellow Pear. The green fruits, which ranged from one-half to two-thirds mature size, were left on the vines. Within 7 days, all of the inoculated fruits were completely or almost completely decayed. All of the varieties were equally susceptible.

SUSCEPTIBILITY OF GREEN AND RIPE FRUITS

Twelve ripe and eight green tomato fruits were punctured and inoculated with the soft-rot organism. Other ripe and green fruits were punctured with a sterile needle and used as controls. All of the inoculated green fruits had rotted completely within 8 days and some of them had dropped from the vines. None of the ripe fruits showed complete decay and only three of them showed slight rotting at the point of inoculation. One of these fruits was completely rotted on the tenth day, while the others, though over-ripe, showed only slight decay at the point of inoculation. The controls remained sound.

A repetition of this test was made with seven ripe and two green fruits inoculated as described above. Two ripe fruits were punctured with a sterile needle for controls. Within 3 days, the green fruits were completely rotted, two of the ripe fruits were partially rotted, three completely rotted, and two remained unaffected.

STEM INOCULATIONS

Stem inoculations were made on the tender tips of six young Norton tomato plants growing in the greenhouse. The inoculum was applied to slits which were made in the tips of the plants with a sterile scalpel. No infection resulted.

Additional stem inoculations were made on two Burbank, two Red Cherry, eight Marvel, six Royal Red, two Norton, and eight Yellow Pear tomato plants. The plants were ten to twelve inches high and the inoculum was introduced into a slit near the tip of each. The plants were watered and left exposed in the greenhouse bed. When examined 3 days later, none of these plants showed infection except the two Royal Red which seemed to be slightly affected. These plants, however, showed no infection when examined a few days later.

Two additional plants of the Royal Red variety were inoculated as described above and placed under bell jars. They appeared to be infected 2 days later, but after 5 days all signs of infection had disappeared.

This evidence indicates that the soft-rot organism is not capable of infecting the stems of the tomato plant.

TEMPERATURE RELATIONS

It had been evident throughout the work that the development of decay by the soft-rot organism was modified by temperature, a longer period being required for complete decay when the greenhouse was cool than when it was warm.

Green tomato fruits of approximately equal size were inoculated by needle puncture and placed in moist chambers each of which was placed in an incubator in which temperatures were maintained as indicated in table 2. Two controls were carried with each lot. The number of days required for complete rotting of all the inoculated fruits varied with the temperature as shown in the table, the most rapid development being at the ranges of 28–34° and 31–34°, and the slowest development at 14–15°. There was no development of rot at 37–42° but the fruits became blackened after 5 days and had a cooked appearance in 7 days. None of the controls showed any rot.

TABLE 2.—*Number of days required for complete rotting of green tomato fruits inoculated with Bacillus aroideae, at the specified temperature ranges*

Temperature range	Number of days
14–15° C.	17
18–22° C.	13
28–34° C.	7
31–34° C.	7
37–42° C.	no rot

OTHER HOSTS

Sweet peppers, cantaloupes, eggplant fruits, and Irish potatoes all proved to be susceptible to decay by the soft-rot organism. When inoculated

by needle puncture and kept in moist chambers at room temperature, sweet peppers were completely decayed in 5 days, eggplant in 4 to 5 days, cantaloupes in 3 days, and Irish potatoes in 7 to 21 days. Townsend (7) has shown that his culture of the organism in question is capable of rotting the corm, petiole, and flower stalk of the calla lily, and the green fruits of tomato, eggplant, cantaloupes, sweet peppers and cucumber. He also reported it as causing rot when inoculated into such vegetables as carrot, potato, turnip, salsify, parsnip, onion, radish, cabbage, and cauliflower.

CONTROL

Data on the control of soft-rot by spraying were obtained in 1918 in an experiment conducted at Blacksburg which has been reported by Fromme (2). Bordeaux mixture of the 5-5-50 formula and soap-Bordeaux (4 pounds bluestone, 3 pounds rosin fish-oil soap, 2 pounds quick lime, 50 gallons water) were applied on two plats and a third plat of the same size served as a check. Five applications of the spray materials were made, the limiting dates being July 6 and August 20. Fruit yields were recorded by weight, the unsound and sound fruits being recorded separately. Practically all unsoundness was due to soft-rot which developed with great severity during an unusually wet period in late August and early September. The total yield for the season from these plats was as follows:

Pounds of fruit	Sound	Unsound
Soap Bordeaux	833	105
Standard Bordeaux	546	207
Check	542	325

The soap-Bordeaux reduced the injury from soft-rot to a marked degree, the percentage control in comparison with the check being 68, while that of standard Bordeaux was 36 per cent. There was no clear explanation for the greater efficiency of the soap-Bordeaux. According to Fromme: "It may have been due to greater bactericidal properties of the spray material, to better covering and adhesion to the fruits, or possibly to foliage protection which decreased sun scald and which would promote more uniform growth of fruit, with fewer growth cracks."

The efficiency of soap-Bordeaux would have been even more pronounced had not the early frost prevented the ripening of the large quantity of green fruit which was left on the plants at the end of the harvest. The soap-Bordeaux plat had 437 pounds of mature green fruit harvested from it after frost and the standard Bordeaux had 424 pounds, while the check yielded only 47 pounds.

SUMMARY

Bacterial soft-rot of tomato, caused by *Bacillus aroideae* Townsend, is capable of causing severe losses in Virginia.

The soft-rot organism is a wound parasite which gains entrance into the tomato fruit chiefly through the growth cracks, sun scalds and insect injuries.

Green tomato fruits are more susceptible to injury from soft-rot than ripe fruits.

All varieties of tomatoes tested were found to be equally susceptible to soft-rot.

The soft-rot organism does not appear to be capable of infecting the stems of the tomato plant.

The optimum temperature for the development of soft-rot appears to be about 30° C.

Losses from soft-rot are appreciably reduced by spraying with soap-Bordeaux.

VIRGINIA AGRICULTURAL EXPERIMENT STATION

LITERATURE CITED

1. EARLE, F. S. Tomatoes. Alabama Agric. Exp. Sta. Bull. 108. 36 p. 1900.
2. FROMME, F. D. Experiments in spraying and dusting tomatoes. Virginia Agric. Exp. Sta. Bull. 230. 15 p., 4 fig. 1922.
3. HUMBERT, J. G. Tomato diseases in Ohio. Ohio Agric. Exp. Sta. Bull. 321: 159-196. 12 fig. 1918.
4. JONES, L. R. A soft rot of carrot and other vegetables. Vermont Agric. Exp. Sta. Ann. Rep. 1899-1900: 299-332. 10 fig. 1901.
5. PRITCHARD, F. J., and W. S. PORTE. Watery rot of tomato fruits. Jour. Agric. Res. 24: 895-905. 1923. Literature cited, p. 905.
6. SHERBAKOFF, C. D. Tomato diseases. Florida Agric. Exp. Sta. Bull. 146: 119-132. Fig. 33-44. 1918.
7. TOWNSEND, C. O. A soft rot of the calla lily. United States Dept. Agric., Bur. Plant Indust. Bull. 60. 47 p., 3 pl., 7 fig. 1904.

A STUDY OF BACILLUS AROIDEAE, TOWNSEND, THE CAUSE OF A SOFT ROT OF TOMATO, AND B. CAROTOVORUS JONES

A. B. MASSEY¹

WITH THREE FIGURES IN THE TEXT

INTRODUCTION

In the summer of 1918, at Blacksburg, Virginia, there developed a considerable amount of a soft rot of tomatoes. This occurred in experimental plots which were designated to study the control of septoria leaf blight, and the soft rot of the fruit developed into an important factor. In describing these experiments Fromme (2) states: "Practically all of the unsoundness of the fruit was caused by bacterial soft rot, a disease which is exceedingly common and often very destructive in tomato fields in Virginia." Isolations from diseased fruits made by S. A. Wingard (15) proved a bacterium to be the causative agent. Its growth in pure culture resembled that of the group of bacteria which causes soft rots of plants but it could not be readily assigned to any of the described species of this group. There has been only casual mention of a bacterial soft rot of tomato in literature, and the distinguishing features of the organisms which might be responsible have not been as sharply defined as is desirable. It was decided, therefore, to undertake comparative studies of the organism in question together with some of the non-chromogenic soft rot forms.

Between the years 1898 and 1904 several species of soft rot bacteria were described. The literature of these is summarized by Harding and Morse (4) in their discussion of comparative cultural studies carried out by them. They describe here the situation of the soft rot forms up to 1909. In 1910 Giddings (2) described, under the name of *Bacillus melonis*, a soft rot bacterium found destructive to muskmelons and also capable of producing rot in some other plants.

Harding and Morse (4) seem to be the only ones who have made extensive comparative studies of the typical soft rot forms. Their studies included four named species (*Bacillus carotovorus* Jones,² *B. oleraceae* Harri-

¹ Paper No. 63 from the Department of Plant Pathology, Virginia Agricultural Experiment Station.

² In accordance to the classification recommended by the Committee of the Society of American Bacteriologists the names used here would be of the genus *Erwinia*, *Bacillus carotovorus* Jones, becomes *Erwinia carotovora* (Jones) comm. S. A. B., and *Bacillus aroideae* Townsend becomes *Erwinia aroidea* (Townsend) comm. S. A. B. These names are recognized but at this transition period it is found that it is clearer to use the old generic name *Bacillus* in this paper where synonymy is involved.

son, *B. omnivorus* Van Hall, and *B. aroideae* Towns.) and 39 strains isolated from various soft rot tissues. All of the 43 strains were alike in the 38 classificatory features studied except in their manner of fermenting the common sugars. *Bacillus carotovorus*, *B. oleraceae* and *B. omnivorus*, together with 30 of the unnamed strains composed one group on the basis that they produced acid and gas from dextrose, sucrose and lactose. *Bacillus aroideae* and three of the unnamed strains composed a second group which showed the characteristic of acid fermentation of these three sugars without gas formation. The six other unnamed strains were intermediate between the two groups and varied in the fermentation of these sugars, some producing acid and gas from one sugar and others from two. This shows a difference which it would seem is hardly sufficient basis for the establishment of distinct species. This is further strengthened by the fact that the gas fermenters are weak in their action. The amount of gas usually being just sufficient to recognize its presence in the fermentation tube. Harding and Morse question the advisability of considering *B. carotovorus* and *B. aroideae* as distinct species. However they recognize the fact that their behavior in pathogenicity may separate them more distinctly or show their close relationship.

COMPARATIVE STUDIES

Recognizing the results of the work of Harding and Morse as sifting the usually termed soft rot forms down at least to the two species, *B. carotovorus* Jones, and *B. aroideae* Town. and probably to one (the former), these two forms, along with the strain from tomato, were included in the study. *Bacillus melonis* was not included since a comparison of Gidding's description of this species and Townsend's description of *B. aroideae* fail to show clear specific differences (See table 3). Giddings does not seem to have compared his organism with *B. aroideae* and Erwin F. Smith who has studied the two together states (12, p. 240) "I think that *Bacillus aroideae* and *Bacillus melonis* are identical."

• Our culture of *B. carotovorus* was secured from L. R. Jones and is a descendant of his original isolation maintained in his laboratory as No. 3a. The culture of *B. aroideae* was provided by Erwin F. Smith. It is not a descendant of Townsend's original isolation, but one isolated by Smith from calla and believed by him to be the true *B. aroideae*.

The investigations here reported are largely as to parasitism of the organisms in plants of the vegetable and floral groups and also their action towards various organic carbon compounds in pure culture. All inoculations and fermentations were carried out in duplicate and were repeated, with a few exceptions to be noted later. The experiments with the three organisms were carried in parallel and maintained under the same conditions.

PATHOGENICITY

The data here reported are as to inoculations carried on in the field, greenhouse and laboratory. All inoculations were by needle punctures into the uninjured healthy tissue. Potatoes, fruit, etc., in the laboratory were not sliced under aseptic conditions and placed in sterile dishes, but the whole structure was thoroughly cleaned and put into moist chambers and inoculated by puncturing with needle. Moist chambers were used which were large enough to accommodate material for two or more separate inoculations and one or two checks; the latter being punctured with sterile needle. In greenhouse and field, inoculations were made in the same manner into plants and plant parts *in situ*.

Methods of inoculation reported by previous investigators, in studying the soft-rot bacteria, have been of two types. The method which has been followed, as mentioned above, was also used by Jones (7) and is to-day largely used in investigations of wound parasites.

Townsend's method (13) of studying the action of *B. aroideae* was largely that of cutting slices of the plant tissue aseptically, placing in sterile petri dishes, dividing the slice into four parts, orienting them in the dish and finally two pieces in each dish "were inoculated with a 24 hour-old beef broth culture on the surface of the pieces and then stabbing through these drops—with a sterile needle." The objections to this method are twofold. The chances of autolysis of the plant tissue is greatly increased over that of the small wound caused by a needle puncture, hence the bacteria find simpler compounds at hand than those which occur naturally in the tissues. Secondly, the addition of a liquid culture to the wounded surface gives a chance for a saprophyte to appear parasitic since it is possible for the extra cellular enzymes to bring about hydrolysis of the compounds of the tissues. This is nicely illustrated in inoculation of the sweet potato with *Rhizopus*. Direct inoculations are rarely successful, but infection is more often obtained when the fungus is placed in contact with the wounded surface along with a broth in which the fungus has been growing.

It has been attempted to repeat as far as possible the inoculations reported by others, with these organisms under parallel conditions. Table 1 summarizes inoculations by previous workers, Jones, (7), Smith (12), and Townsend (13), and the results obtained by the author, with the two named organisms and the tomato strain.

The majority of inoculations made in the plants shown in table 1 gave the same results as have been before reported by other workers. As a whole, the negative and positive inoculations indicate a very close relationship between *B. carotovorus* and *B. aroideae*, and show the identity of the tomato strain with *B. aroideae*. They are sharply distinguished, however, by the reaction with certain hosts, notably cauliflower, kohlrabi, and tobacco. The

TABLE 1.—Results of inoculations of soft rot bacteria into vegetables, fruits and tobacco.
O indicates no soft rot developed; + typical soft rot developed; blank spaces occur where no report has been made, or in author columns, inoculations not made.

	<i>B. carotovorus</i>			<i>B. aroideae</i>		Tomato strain
	Jones	Smith	Author	Townsend	Author	Author
Apple, ripe	O		O	O	O	O
Banana, green			O		O	O
Banana, ripe	O		O	O	O	O
Beet root	O		O		+	+
Cabbage	+		+	+	+	+
Carrot, root	+	+	+	+	+	+
Cauliflower	O		O	+	+	+
Celery	+		+		+	+
Cucumber		+	+	+	+	+
Eggplant fruit	+		+	+	+	+
Kohl-rabi			O		+	+
Lettuce		+	+			
Muskmelon		+	+	+	+	+
Onion, young leaf	+		O	O	O	O
Onion, mature	+		+	+	+	+
Parsnip	+		+	+	+	+
Pepper, fruit	+		+	+	+	+
Potato, sweet, root	O		O		+	+
Potato, white, tuber	O	+	+	+	+	+
Potato, white, stem	O		O		O	O
Radish	+		+	+	+	+
Salsify	+		+	+	+	+
Tomato, fruit	+		+	+	+	+
Tomato, young stem	O		O	O	O	O
Turnip, root	+		+	+	+	+
Tobacco, stem			O		+	
Tobacco, suckers			O		+	

type of rot produced by the two named organisms is very similar in all cases. Occasionally one finds a slight difference in the color and odor of the disorganized tissues. The results obtained with certain of the hosts are described in the following.

Cauliflower: The writer's inoculations with *B. carotovorus* in the cauliflower were negative agreeing with those of Jones while the inoculations with *B. aroideae* are positive and agree with those of Townsend. It was noticed, however, that the inoculations with *B. carotovorus* developed an initial appearance along a line of punctures as though rot were setting in. However, this initial appearance soon disappeared resulting in no disorganization of the tissue beyond the needle punctures. With *B. aroideae* and the tomato strain this initial appearance developed during the first 24 hours and was followed by rapid discoloration and general breaking down

of the tissues, typical of the soft rot. Harrison (5) reported a soft rot of the cauliflower by his *B. oleraceae*, and Harding and Morse (4), on the basis of their cultural studies, placed Harrison's bacillus in a group with *B. carotovorus*. Jones, as mentioned above, noticed a difference in the enzymatic activity of some soft rot forms. He found Harrison's bacillus to be more active than *B. carotovorus* but not as active as *B. aroideae*. It appears, therefore, that the enzymatic activity of *B. carotovorus* is not such as to enable it to carry out the disorganization of the cauliflower tissue.

Kohl-rabi: A number of inoculations were made into kohl-rabi "balls" both in moist chambers in the laboratory and in the "balls" growing in the

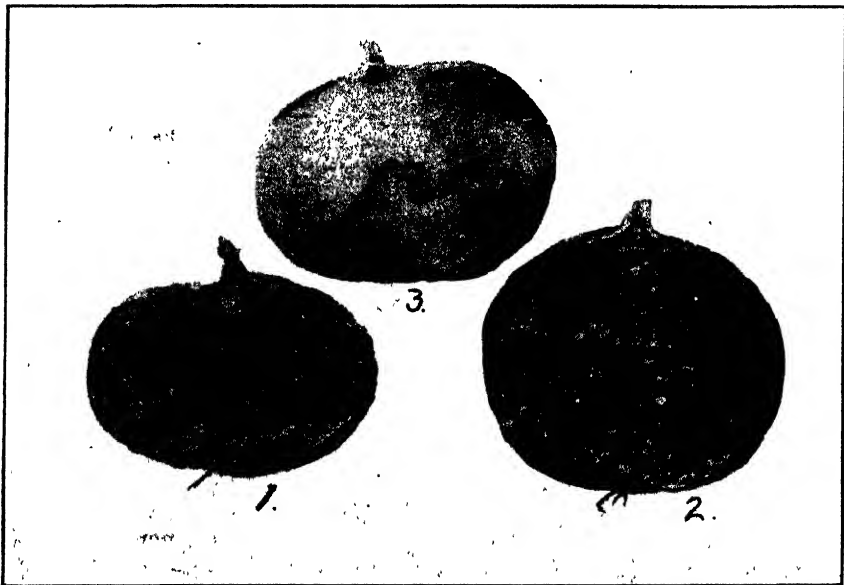


FIG. 1. Soft rot of Kohl-rabi balls induced by inoculation with (1) *Bacillus aroideae* and (2) the tomato strain; (3) Check, punctured with sterile needle.

greenhouse and in the field. The inoculations made with *B. aroideae* and the tomato strain developed rapidly into a mushy rot involving the parenchyma which is enveloped by the fibrous outer layer of the "ball." The rot does not become evident externally for a number of days. A foamy secretion is often noticed from the point of inoculation giving evidence of a considerable gas production. In a firm, succulent "ball" the internal break-down progresses rapidly and in about a week, occasionally in five days, the collapse of the outer wall of the "ball" becomes marked. In figure 1 are shown sections of kohl-rabi "balls" cut three days after inocula-

tion. No. 1 was inoculated with *B. aroideae*; No. 2 with the tomato strain; the upper figure, No. 3, is a check. In these figures are shown the general break-down of the tissues but no effect on the wall of the "ball." The odor of the decayed kohlrabi is very disagreeable, of the nature of spoiled cabbage but stronger.

The inoculations made with *B. carotovorus* developed initial appearance as described in inoculations of cauliflower with this organism. The change did not go beyond this and even the initial appearance very soon disappeared. Checks which were produced by punctures with sterile needles did not show this change as was the case with the *B. carotovorus* inoculations; hence it could not be considered a case of traumatism.

Onions: Inoculations into mature onion bulbs developed rot in the case of all three organisms. However, the development of the rot by the *B. aroideae* and the tomato strain was slow. Townsend also found rot development in this host to be slow. The inoculations made by *B. carotovorus* developed into a more rapid rot and involved a larger area of the bulb. Only those bulb scales which were punctured with the inoculating needle were affected. The scales beyond the needle puncture become infected rarely and then apparently only through wounds caused by other agencies. Inasmuch as the organism is a wound parasite, this is exactly what might be expected since the bulb of course consists largely of succulent leaf bases. Inoculations into young onions were negative in both cases. Jones reports successful inoculations into the leaf. From his description, however, it would seem that the inoculations were made into the leaves of the sprouts from mature onions which were in moist chambers. The young leaves used in inoculations made here were those on young plants growing in soil in the greenhouse.

From this the conclusions to be drawn agree with the accepted facts to be found in the literature of today. Bacterial rot of the onion would not become troublesome in the field until late in the growing season when the bulb is maturing, its most serious damage more often developing in storage or transit and *B. carotovorus* being more actively responsible.

* *Sweet potato:* Jones reports inoculations of *B. carotovorus* into sweet potatoes as unsuccessful and my tests with this organism were also negative. In the first experiments with the sweet potato *B. aroideae* and the tomato strain also proved non-pathogenic. All of these first inoculations were made into roots bought on the market. Later inoculations were made into roots freshly dug from the ground. In these *B. carotovorus* proved non-pathogenic while *B. aroideae* and the tomato strain developed a soft rot involving a small area of the root. The decay caused by *B. aroideae* was not extensive and it is not believed that it would develop a serious soft rot of the sweet potato.

White potato: Inoculations made into the tuber of the white potato from the market or from local storage did not develop pathogenically for *B. carotovorus* but did develop pathogenically in the case of inoculations with *B. aroideae* and the tomato strain. In the latter the decay was rapid and discoloration of the tissues was very marked, being similar to that produced by the blackleg organism. Later inoculations with *B. carotovorus* and *B. aroideae* into tubers recently dug developed into a rot in all cases the same results have been repeated by the writer several times. In these freshly dug tubers the rot by *B. carotovorus* is not essentially different from that produced by *B. aroideae*.

Tobacco: Johnson (6) observed a decay of the tobacco stems in the field which resulted in the development of a hollow stalk. He gives brief mention of the trouble and states that he isolated a bacterium from the diseased tissue with which he was able to reproduce the disease in other plants. He considered the organism one of the soft rot bacteria. More recently reports have come from Connecticut and Massachusetts of isolated cases of the same disease. In these latter cases it seems that no isolations of the organism were made and little or no attempt was made to establish its identity. The writer has made inoculations into tobacco stems and the stem of tobacco suckers with both *B. carotovorus* and *B. aroideae*. Inoculations made with *B. aroideae* developed a rapid browning of the pith followed by a general soft rotting and collapse resulting in a disappearance of the pith of the stem; consequently the "hollow stalk." These inoculations developed very markedly in 36 hours under greenhouse conditions (see figure 3). The inoculation made with *B. carotovorus* did not develop any discoloration or any disorganization of the tissues of the tobacco stalk.

The hollow stalk disease has been described as entering the base of the stalk or the tip and rapidly developing throughout the pith of the stalk and into the petiole and larger veins of the leaf. One plant becoming infected in the field through some wound may easily develop a source for spread of infection by various agencies, especially by the knife in topping. Clinton mentions an isolated occurrence of the disease in Connecticut and states that there are usually two or three plants together in the field. The writer has not found any report of any extensive development of hollow stalk. However, it is possible that the disease has been mistaken for the manifestations of other organisms. Specimens of diseased tobacco plants have been received from Virginia which were difficult to place and it seems probable now that some of these may have been cases of hollow stalk caused by *B. aroideae*. It is possible to confuse hollow stalk and tobacco wilt (*B. solanacearum*) on casual examination.

Striking differences in pathogenicity are also found among the floral plants, especially so in the calla lily and in the wild and cultivated iris. The results of inoculations into floral plants are presented in table 2.

TABLE 2.—*Results of inoculations of floral plants with soft rot bacteria.*

	<i>B. carotovorus</i>	<i>B. aroideae</i>	Tomato strain
Common Calla Lily, petiole <i>Zantedeschia aethiopica</i> . Var. <i>Minor</i>	O	+	+
Golden Yellow Calla, petiole <i>Zantedeschia Elliottiana</i>	O	+	+
Elephant Ear, petiole <i>Caladium esculentum</i>	O	O	O
Garden Gladiolus, green leaf	O	O	O
Blue Flag <i>Iris versicolor</i> } Leaf	+	O	O
Wild Spring Iris } Leaf <i>Iris verna</i>	+	O	O
Hyacinth, Scape	+	+	+

As is noted in the table none of the organisms infected the elephants' ear nor the gladiolus, and all proved positive for the hyacinth. The action towards calla and iris is especially striking and is detailed as follows:

Calla lilies: Toward this host *B. aroideae* and the tomato strain are markedly pathogenic while *B. carotovorus* is not at all so. This is the host from which Townsend first isolated his organism. The usual illustration of the effect of this organism on cells shows the breaking down of the tissues over a limited area of the petiole. Such is not the most striking manifestation of the disease. The limited area rapidly enlarges resulting in a general destruction of the host as shown in figure 2. Leaf blade inoculation likewise results in a disorganization of the tissues. Inoculations from vigorous cultures into a good healthy petiole will show infection within 24 hours while those made into old petioles are slow in development. The writer has found this host to be the most satisfactory one for proving out *Bacillus aroideae*.

Iris: Inoculations into this host gave opposite results from the calla inoculations. *B. carotovorus* proved pathogenic while *B. aroideae* and the tomato strain did not. These inoculations were made mostly into the green leaf under very humid conditions. Infection is apparent as a general breaking down of the leaf tissues in a circular fashion around the needle puncture. Diseased areas on leaves which develop during periods of high humidity dry up and fall out when the humidity decreases, giving the appearance of shot hole, or if they occur on the edge of the leaf, resemble more the depredations of insects.

Observations for several years in a local garden where soft-rot of tomato has been destructive are of interest. In this garden soft rot of carrots, white potatoes, parsnips, cucumber, muskmelon and other plants was common while no rhizome or leaf rotting of iris has appeared. Irises taken from this garden proved by inoculations to be susceptible to *B. carotovorus*.



FIG. 2. Calla lily plants inoculated in petiole (1) with *B. carotovorus*, (2) with *B. aroideae*. No infection results from *B. carotovorus* inoculations.

Iris has been reported as subject to bacterial soft rot by several workers and it is not an uncommon disease. Specimens have been received from two localities in Virginia. Van Hall (14) described a disease of the young shoots caused by his *Bacillus omnivorus* (which according to the work of Harding and More mentioned at the outset, comes to *B. carotovorus*) on *Iris florentina* and *I. germanica*. Richardson (10) reports *B. carotovorus* as the cause of soft rot of iris in Canada. Shull (11), in a popular article, described the disease and measures of control.

Miss Lacy (9), in a short note, reports a soft rot of violet caused by *B. carotovorus*. So far our inoculations have all been negative. Difference

in varieties and conditions under which grown most likely is the explanation. The plants used in our work were cultivated forms that received no care. Miss Lacy's plants were from a garden where they were attended to and the growth was very likely much more succulent than was the case of the plants used in this experiment. Miss Lacy gives a very brief description of the organism she isolated and found to be parasitic and mentioned



FIG. 3. Longitudinal section of tobacco stem 36 hours after inoculation with *B. aroideae*, showing disintegration of the pith.

that it corresponded favorably with *B. carotovorus* in culture in her laboratory but does not state that the pathogenicity of the latter organism was determined.

FERMENTATION

* Cultural differentiation of *B. carotovorus* and *B. aroideae* has been mainly based upon the fact that the former produces gas where the latter does not. Bearing in mind the small amount of gas produced by *B. carotovorus* it makes the cultural differentiation rather uncertain.

The action of the organisms toward various organic carbon compounds were studied for the most part in solution. The cultures were grown in 150 cc. Erlenmeyer flasks, each containing 25 cc. of the culture solution. The solution was prepared by dissolving the total amount of organic carbon compound in four-fifths of the total amount of distilled water to be used. The concentrations of the organic compounds used are shown in table 4. After the solution was all dissolved 20 cc. portions were measured with

pipette into the flasks. These were plugged with cotton wool and sterilized in the autoclave under 15 pounds steam pressure for 15 minutes. Thus the carbon compounds were sterilized in the presence of the distilled water only. To each of these flasks was next added 5 cc. of sterile 2.5 per cent Bacto peptone solution. The transfer to the flasks was accomplished by means of sterile pipettes under guarded conditions to prevent contamination from the air. This made a peptone concentration of 0.5 per cent in each flask. After the sterile peptone solution had been added the flasks were incubated for three days to develop any contaminations. The percentage of contaminated flasks was very small.

The flasks were inoculated from 24-hour peptone broth cultures by putting into the flasks 2-3 drops of the culture from a pipette. The inoculated flasks were incubated at 25°-30° C. The hydrogen-ion concentration was determined at intervals to note the development of acidity and final pH. These determinations were made colorimetrically by comparing with standard buffer solutions containing the proper indicator. For detecting gas fermentation the agar shake method was used. The media was prepared in the same manner as described for the liquid cultures, *i.e.* by sterilizing the component parts separately. At first the oxygen relation in such cultures was questioned but experiments as shown in tables 5 and 6 cleared this point.

Table 3 summarizes the action of *B. carotovorus*, *B. aroidcae* and *B. melonis*, as reported by Jones (7), Townsend, (13) and Giddings (3), respectively, and by Smith (12) for *B. carotovorus*, on some of the common organic compounds used in culture studies.

As shown in table 3 the three organisms are not distinguished on the basis of acid production, but *B. carotovorus* differs from the others in gas production. The amount of gas is often slight and this has not been considered a sufficient basis for separation by Harding and Morse (4).

The table shows how impossible it would be to separate Giddings's bacillus from *B. aroidcae* in such cultures.

The fermentations here reported were carried out to determine the actions of *B. carotovorus* and *B. aroidcae* toward a larger number of organic compounds in hope of showing stronger their relationship. This was carried out by observing the acid and gas fermentation of the following:

Alcohols

Monohydric—Ethyl, Butyl,

Polyhydric—Glycerol, Mannitol,

Aldehyde—Vanillin

TABLE 3.—*Gas and acid fermentation by B. carotovorus, B. aroideae, and B. melonis as gathered from literature.*

	<i>B. carotovorus</i>				<i>B. aroideae</i>		<i>B. melonis</i>	
	Gas		Acid		Gas	Acid	Gas	Acid
	LRJ	EFS	LRJ	EFS	Townsend		Giddings	
Dextrose	+	+	+	+	O	+	O	+
Lactose	+	+	+	+	O	+	O	+
Sucrose	+	+	+	+	O	+	O	+
Maltose					O	+	O	+
Mannitol	+	+	+	+	O	+	O	+
Glycerol	O	O	+	+	O	+	O	+
Muscle sugar		+		+				
Milk	O	O	+	+	+	+	+	+

* Giddings's results indicate acid development from maltose at 25° C. during first four days to be about pH 6.8, on 18th day about pH 7.4. Townsend's determinations were in twenty-weeks'-old cultures using litmus indicator.

** Reported by Smith (4). Townsend did not test the action of his organism on milk in fermentation tubes.

Monosaccharides

Pentoses—Arabinose, Xylose,

Methylpentose—Rhamnose,

Hexoses—Dextrose, Galactose, Levulose

Disaccharides—Saccharose, Maltose, Lactose,

Trisaccharides—Raffinose,

Polysaccharides—Starch, Dextrin,

Glucosides—Amygdalin, Esculin, Salicin, and Arbutin.

This selection presents a series of organic carbon compounds of varying complexities and was made with the hope of bringing out differences in the organisms through the selective action of their enzymes, that is, through the relationship between molecular configuration of the compounds and enzymatic action.

In the beginning it was realized that by observing only the acid and gas fermentations, the chances of finding differences in the action of the organism were limited. However, for practical differentiation of the organisms in culture a more detailed chemical study of the fermentation, as to the kind and amount of cleavage products, though interesting, and valuable, would not necessarily aid in readily distinguishing the organisms in cultures. It is hoped later to go into the study of these cleavage products which should help to explain points that come to mind in this study, and by chance throw

some light on the cause of resistance and susceptibility in plants to these bacteria.

The results of the fermentation of the compounds listed above, exclusive of the glucosides, are shown in Table 4. The hydrolysis of the glucosides is given in table 5. The relationship of the action on the mono-, di- and trisaccharides (exclusive of maltose) is the same as that shown by previous studies in the fermentation of the usual laboratory sugars. That is, *B. carotovorus* produces acid and gas, while *B. aroideae* and the tomato strain develop acid fermentation only.

The action towards maltose is contrary to previous reports. The writer found a slight rise in the H-ion concentration during the first 48 hours, but the action soon reverses. The figures in parenthesis opposite maltose is the pH. reading at the end of 24 hours. The most feasible explanation of this small acid development is that there seemed to be a trace, not readily detected, of inverted maltose in the culture. This was fermented with development of slight acidity and when used up, maltose proving unfavorable, the protein molecules are attacked to satisfy the carbon as well as the nitrogen requirements in the metabolism of the bacteria. The excess nitrogen being eliminated in the form of ammonia would increase the hydroxyl concentration. An analogous action towards the polysaccharides was found, though no initial rise in the pH.

Bio-chemical studies of the enzymes have shown that *emulsin* is commonly responsible for the hydrolysis of glucosides of the beta type, while the alpha-glucosides are hydrolyzed by the enzyme *maltase*. The beta-glucosides, amygdalin, aesculin, salicin, and arbutin were hydrolyzed by both organisms which indicates the presence of the emulsin complex in the cultures of these organisms. Maltose, glucose alpha-glucoside, is not hydrolyzed by these bacteria which indicates the absence of *maltase*. Demonstrating the presence of emulsin helps in further interpretation of table 4. Lactose, a glucose beta-galactoside, is more actively hydrolyzed by lactase. Some preparation of the emulsin complex from almonds has been found capable of hydrolyzing lactose. The tri-saccharide, raffinose, is hydrolyzed by both emulsin and invertase; emulsin converting it to sucrose and galactose and invertase to fructose and melibiose. Melibiose (glucose beta-galactoside) is slowly acted upon by emulsin. Finding evidence of the presence of emulsin and invertase in cultures of these bacteria give a clearer understanding of the action shown towards the di- and tri-saccharides of table 4. Through the enzymatic action these compounds (exclusive of maltose) are hydrolyzed to the simpler monosaccharides and these are in turn fermented forming acid on the one hand and acid and gas on the other. It is in the fermentation of the monosaccharides that a careful bio-chemical study would be of interest and likely instructive as to the physiology of these closely related forms.

TABLE 4.—*Acid and gas fermentations by B. carotovorus and B. aroideae.*

	<i>B. carotovorus</i>			<i>B. atroideae</i> *		
	H-ion concentration		Gas	H-ion concentration		Gas
	At start	4-day culture	7 days	At start	4-day culture	7 days
<i>Alcohols and Aldehyde</i>						
Ethyl	4.0 %	6.8	5.2	—	6.8	7.4
Butyl	0.5 %	6.8	7.0	—	6.8	7.2
Glycerol	6.0 %	6.8	6.8	—	6.8	7.0
Mannitol	1.0 %	6.8	5.0	+	6.8	5.0
Vanillin	0.02%	6.6	6.2	—	6.6	6.4
<i>Monosaccharides</i>						
Arabinose	1.0 %	7.2	5.6	+	7.2	5.6
Xylose	1.0 %	6.6	5.6	+	6.6	5.6
Rhamnose	1.0 %	7.0	5.2	+	7.0	5.4
Dextrose	1.0 %	6.6	5.0	+	6.6	4.4
Galactose	1.0 %	6.2	5.2	+	6.2	5.4
Levulose	1.0 %	6.6	5.2	+	6.6	5.4
<i>Di- and Tri-Saccharides</i>						
Sucrose	1%	6.8	5.0	+	6.8	5.0
Maltose	1%	6.8 (6.2)	7.8	—	6.8 (6.4)	7.2
Lactose	1%	6.4	5.2	+	6.4	5.4
Raffinose	1%	7.2	5.4	+	7.2	5.2
<i>Polysaccharides</i>						
Starch	1%	7.2	7.6	—	7.2	8.0
Inulin	1%	7.2	8.0	—	7.2	8.2

* The tomato strain agreed with the *B. aroideae* throughout.

The action on ethyl alcohol is of interest as it gives an additional means of cultural differentiation. The acid development from ethyl alcohol is very marked with *B. carotovorus* while it is entirely absent in cultures of *B. aroideae*. Growth in peptone broth containing ethyl alcohol is very striking. *B. carotovorus* produces a heavy pellicle and an abundant growth, while *B. aroideae* produces a very slight growth. This is well illustrated by Smith (12, fig. 184). The writer is not aware of acid fermentation of alcohol by *B. carotovorus* being previously recorded. By use of an alcohol-peptone, Brom-cresol-purple agar the two forms are readily separated as *B. carotovorus* quickly develops acid which changes the indicator from purple to yellow. *B. aroideae* grows on this agar, but there is no change in the color of the indicator.

The method of preparing the alcohol medium is as follows: The agar base contains 1 per cent peptone, 1.8 per cent agar shreds, and Brom-cresol-purple in distilled water. This is dissolved, tubed (8 cc. per tube) and sterilized. Just before use the agar is melted, cooled to 45° C. and 0.4 cc. of 95 per cent ethyl alcohol is added. The tube is rolled to mix and is quickly cooled as a slant. This can be held to prove its sterility if desired. The concentration of alcohol is 5 per cent. Ten per cent alcoholic concentration is not prohibitive to *B. carotovorus*, but seems to be to *B. aroidae* though the tolerance of the forms to alcohol has not received the writer's attention.

Stroke culture on agar of this type reveals acid development very prettily. For isolating *B. carotovorus* from rotted tissue it is of course essential that the plates be poured when the agar is first made on account of the volatility of the alcohol. On these plates *B. carotovorus* is readily isolated by fishing the acid developing colonies. If the rot is due to *B. aroidae* fishing from amoeboid non-acid colonies will assist in isolation.

The writer has also studied authentic cultures of *B. phytophthorus* and *B. atrosepticus* on alcohol-agar and both show no acid or gas production. They disagree with *B. carotovorus* in this respect although they are like it in a number of other respects according to facts gathered from literature and unpublished studies of the writer.

OXYGEN REQUIREMENTS

The growth of the soft rot forms in the closed arm of Smith fermentation tubes brought to mind the question of oxygen requirements. This was tested out in the presence of dextrose only. Two experiments were set up: The pH development was studied, first, in flasks and tubes presenting different surface areas exposed to the air of the vessel and second, in tubes with sterile vaseline covering the surface of the medium.

Experiment No. 1. pH development in dextrose peptone broth under varying surface area exposures. A dextrose peptone broth (peptone 0.5 per cent, dextrose 1 per cent) was prepared in bulk and then distributed in 25 cc. quantities in small (150 cc.) Erl. flasks 6.5 cm. in diameter at the surface of the liquid and large test tubes of 2.5 cm. diameter. After sterilization six of each were inoculated and each day for three days two cultures of each bacterium were used to determine the pH. Just prior to making pH determination in a culture the broth was thoroughly mixed and then determinations were made colorimetrically. The results are given in table 5.

Bacterium angulatum (Fromme & Murray) and *Bacterium tabacum* (Wolf & Foster) are included to show more strikingly the effect of surface area exposed on H-ion development. The tobacco bacteria are strict aerobes;

they do not grow in closed arm of Smith fermentation tube. This demonstrates the facultative nature of the soft rot forms. The availability of free oxygen is not a factor in the fermentation of the carbohydrates by them. The case is different with the tobacco leaf spot organisms. Also it is demonstrated clearly that it is necessary to consider the surface area of the culture in studies of H-ion development unless preliminary experiments show the organism to be a facultative form.

TABLE 5.—Development of H-ion concentration in dextrose broth with varying surface area exposure.

Bacteria studied	24-hour culture		48-hour culture		72-hour culture	
	Square centimeters in exposed surface					
	44.18	5.03	44.18	5.03	44.18	5.03
	pH	pH	pH	pH	pH	pH
<i>B. carotovorus</i>	5.0	5.0	5.0	4.8	4.8	4.8
<i>B. phytophorus</i>	5.2	5.2	5.0	5.0	5.8	4.8
<i>B. aroideae</i>	5.0	5.0	5.0	4.8	4.8	4.8
<i>Bact. tabacum</i>	5.2	7.0	5.0	6.4	4.8	6.6
<i>Bact. angulatum</i>	5.6	7.0	5.0	5.4	4.8	5.0
Control	6.6	6.6	6.6	6.6	6.6	6.6

Experiment No. 2. The pH development from dextrose in culture tubes with sterile vaseline covering the medium (Brown's (1) vaseline tube). The medium used here was the same as in the previous experiment; 10 cc. were placed in test tubes 1.5 cm. in diameter and then sterilized in the autoclave. As soon as the autoclave could be opened the tubes were taken out and about 1 cc. of melted sterile white vaseline was placed in each tube. In this way the chances of oxygen being absorbed were slight, if any. After cooling these were inoculated from agar cultures. The inoculation was made direct into the medium by holding the tube at about 45° angle and gently melting the edge of the vaseline which slips, thereby exposing the medium. After inoculation the vaseline plug is melted by holding the tube in the flame, tube placed upright, and the vaseline solidifies over the surface of the medium. That this vaseline seal is effective is shown by the fact that 9 tubes of broth prepared in this way, but not inoculated, standing for eleven months in the open laboratory, with only the protection of the cotton plug, show less than 1 mm. shrinkage.

The results of these anaerobic cultures are shown in table 6.

SUMMARY

A bacterial soft rot of tomato is here shown to be caused by *Bacillus aroideae* Townsend.

TABLE 6.—Development of H-ion concentration and gas in vaseline sealed tubes in presence of dextrose.

	pH	5-day-old culture	Gas
<i>B. carotovorus</i>	4.8		+
<i>B. aroideae</i>	4.8		O
<i>B. phytophthorus</i>	4.8		+
<i>Bact. tabacum</i>	6.6	No growth	O
<i>Bact. angulatum</i>	6.6		O
Control	6.6		O

Comparative studies of *B. aroideae* and *B. carotovorus* Jones, indicate the close relationship of these two forms, but they may be readily differentiated by either laboratory cultures, pathogenicity, or, better, by a combination of the two.

Bacillus carotovorus and *Bacillus aroideae*, though closely related, should be maintained as separate species.

The following scheme summarizes the differentiation of the two organisms:

I CULTURAL AND FERMENTATION CHARACTERS

	<i>B. carotovorus</i>	<i>B. aroideae</i>
Agar colonies in thinly sown plates	round, entire	amoeboid
Fermentation of: dextrose, lactose, galactose, saccharose, mannitol, etc.	acid and gas	acid without gas
Action in ethyl alcohol media	acid without gas, heavy pellicle and abundant growth.	no acid or gas, no pellicle and slight growth.

II PATHOGENESIS

Inoculation into:

Calla	negative	positive
Iris	positive	negative
Kohl-rabi	negative	positive
Cauliflower	negative	positive

Studies of the oxygen requirements demonstrate the facultative nature of the soft rot forms and bring out the importance of stating the area of

the exposed surface of a broth in studies of H-ion concentration if the organism is not a facultative type.

Acknowledgments are due to Dr. F. D. Fromme for constructive suggestions and criticisms of these investigations and especially in the final shaping up of the manuscript.

LITERATURE CITED

1. BROWN, J. H. The vaseline tube and syringe method of micro gas analysis of bacterial cultures. Jour. Exp. Med. 35: 667-684. 1922.
2. FROMME, F. D. Experiments in spraying and dusting tomatoes. Virginia Agric. Exp. Sta. Bull. 230. 15 p., 4 fig. 1922.
3. GIDDINGS, N. J. A bacterial soft rot of muskmelon, caused by *Bacillus melonis*, n. sp. Vermont Agric. Exp. Sta. Bull. 148: 361-416. 1910. Bibliography, p. 415-416.
4. HARDING, H. A., and W. J. MORSE. The bacterial soft rots of certain vegetables. I—The mutual relationships of the causal organisms. Vermont Agric. Exp. Sta. Bull. 147: 243-279. 1910.
5. HARRISON, F. C. Preliminary notes on a new organism producing rot in cauliflower and allied plants. Science 16: 152. 1902.
6. JOHNSON, JAMES. The control of diseases and insects of tobacco. Wisconsin Agric. Exp. Sta. Bull. 237. 34 p., 9 fig. 1914.
- ✓ 7. JONES, L. R. A soft rot of carrot and other vegetables caused by *Bacillus carotovorus* Jones. Vermont Agric. Exp. Sta. 13th Ann. Rept. 1899-1900: 299-332. 1901.
8. ————. The bacterial soft rot of certain vegetables. II—Pectinase, the cytologic enzyme produced by *Bacillus carotovorus* and certain other soft-rot organisms. Vermont Agric. Exp. Sta. Bull. 147: 283-360. 1910. Bibliography, p. 357-360.
9. LACEY, M. S. Studies in bacteriosis. VI—*Bacillus carotovorus* as the cause of soft rot in cultivated violets. Ann. Appl. Biol. 9: 169-170. 1922.
10. RICHARDSON, J. K. A study of soft rot of iris. 15th Ann. Rept. Quebec Soc. Prot. Plants 1922-1923: 105-120. Pl. 5-7. Bibliography, p. 120.
11. SHULL, J. M. Iris root rot. Flower Grower 8: 32. 1921.
12. SMITH, E. F. Bacterial diseases of plants. Philadelphia and London. 1920.
- ✓ 13. TOWNSEND, C. O. A soft rot of the calla lily. United States Dept. Agric. Bur. Plant Ind. Bull. 60. 47 p., 9 pl., 7 fig. 1904.
14. VAN HALL, C. J. J. Das faulen der jungen schlosslinge und rhizome von *Iris florentina* und *Iris germanica*, verursacht durch *Bacillus omnivorus* v. Hall und durch einige andere bakterienarten. Zeitschr. f. Pflanzenkr. 13: 129-144. Illus. 1903.
15. WINGARD, S. A. Bacterial soft rot of tomato. Phytopath. 14: 451-459. 1924.

EXPERIMENTS IN CONTROL OF CANKERS OF PEAR BLIGHT

L. H. DAY

WITH ONE FIGURE IN THE TEXT

The term canker as herein used in relation to the pear blight disease (*Bacillus Amylovorus*) refers to the diseased area of the bark in larger branches. These areas or cankers may vary in size from a fraction of an inch in diameter up to areas surrounding the whole branch or trunk and may extend along such parts for many feet.

It is a quite current opinion held by pear growers and many plant pathologists who have not taken particular notice of the literature on the subject or of the lesions of the disease in the bark, that the disease is primarily in the cambium layer. In fact this statement is quite common in texts, bulletins and articles on pear blight. A number of authors, however, have pointed out the fact that this is not the case, and that the disease often kills only the outer bark. In California where the Bartlett pear industry has usually been very profitable, growers have gone to great expense in fighting blight and in attempts to save larger branches which have become infected. For many years the more progressive growers made a practice of going over their orchards every week or ten days and cutting out the affected areas of bark (cankers) in larger branches before the disease had a chance to progress all the way around. The bark was cut to the wood and some disinfectant applied. Finally, about 1916, one grower, Mr. Hayward Reed, of Sacramento, having noticed that the disease progressed in the outer bark for several weeks before it penetrated inwardly to the cambium layer, tried on a rather large scale, the idea of shaving off only the outer bark over the cankers and applying disinfectants. This method gave considerable promise. Many of the cankers were arrested and the uninjured cambium regenerated a new bark within the season. This method was taken up by a number of growers and gained considerable favor until in the virulent outbreak in 1920-21 it failed completely. At this juncture the writer began an investigation of the matter to determine the possibilities of the method and to try to perfect it, if it seemed feasible.

Hundreds of cankers were scarified, that is, the outer bark shaved off, and treated with various disinfectants. It became evident that there was considerable promise in the method. Reimer's formula consisting of cyanide of mercury and bichloride of mercury, one part each in 500 parts of water, by weight, was the most commonly used disinfectant. However, it was not penetrating enough. Apparently the water evaporated too quickly and left the chemical dry and inactive on the scarified bark. In the spring of 1922, I had a student scarify some thirty-five or forty cankers, to half of which

was applied the Reimer formula in water and to the other half the same disinfectants dissolved, in the same proportions, in a solution consisting of one part water and three parts of glycerine. This latter formula arrested



FIG. 1. Pear blight canker scarified from near the ground and a short distance up each scaffold. The cambium was saved under this canker and a new bark generated.

all the cankers treated while the other gave only thirty-five per cent control. This method and formula is now used by hundreds of pear growers in Cali-

fornia. Those who understand the method of scarifying and have careful workmen secure a high percentage of control, possibly from 80 up to 95 per cent. The older that cankers become the deeper they penetrate and the more difficult to arrest. The grower goes over the orchard every week or ten days to find these cankers before the disease becomes too deep.

The method of operating is as essential as the disinfectant formula used. The dead outer bark must be shaved down until most of the diseased tissue is removed. Thick bark in crotches, and around branch collars and old bud scars must be pared nearly to the cambium. However, if pared too deeply the disinfectant will kill the cambium. Not the least speck of epidermal bark should be left in the diseased area for the disinfectant will not penetrate the waxy covering of the bark. The bark must be shaved for four or five inches beyond the ends of the canker. These various details of course can only be learned by experience.

A long bladed jack-knife is a good tool for shaving the bark but the growers have improvised various "scrapers" for this work. The photograph shows a pear tree scarified from near the ground and up each scaffold for a distance of about one foot. It required about one hour to perform this operation.

The author has tried to accomplish these same results with penetrating and caustic chemicals painted onto the bark to take the place of the more laborious surgical operation. Scores of different chemicals have been tried. Some have given promise but there are a number of factors which make this a difficult problem. Branches differ in the readiness with which they take in chemicals. Trees in different orchards vary in this respect, and they vary from season to season in a rather large range. The diseased area usually absorbs chemicals more readily than does the healthy tissues at the margins of the canker, especially in older cankers. The range between a concentration of chemicals sufficient to kill the bacteria and one that will not overpenetrate and injure the cambium is too close to make any of the materials yet tried very satisfactory. The iodine salts have been the most promising, especially zinc iodine and potassium tri-iodide. A fifteen per cent solution of zinc iodide has stopped practically all cankers treated but it over-penetrates so frequently in the older cankers, that many branches are lost that could have been saved by scarification.

Then, of course, varieties of pear trees differ in the readiness with which the bark absorbs chemicals and also the blight runs deeper in some varieties than in others. Possibly in some climates the blight may run deeper than in others so that methods that may be successful in California may not be successful in other places.

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The September Number of Phytopathology was issued October 6, 1924.

PHYTOPATHOLOGY

VOLUME XIV

NUMBER 11

NOVEMBER, 1924

THE EFFECT OF HYDROGEN-ION CONCENTRATION ON THE EXTRACELLULAR PECTINASE OF *FUSARIUM CROMYOPHTHORON*

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INTRODUCTION

The action of pectinase in the hydrolysis of pectin and in the maceration of vegetable tissues has been studied by many investigators. The results of these different workers indicate that distintegration of vegetable tissues by fungi and bacteria is due to an enzyme or a group of enzymes called, collectively, peectolytic enzymes. The different members of the group are recognized by their specific function: pectosinase, being the enzyme which converts pectose to pectin; pectase, the one which coagulates pectin, and finally, pectinase, that which hydrolyses pectin to reducing sugars of the pentose series, probably, to d-galactose and l-arabinose.

LITERATURE CITED

Pectinase is reported in the literature as being intracellular (that obtained from within the cell) and extracellular (that obtained from the solution surrounding the cell). Pectinase obtained from either source is shown to possess identical properties.

Jones (6) who conducted extensive researches with *Bacillus carotovorus* Jones, found that his organism secreted an enzyme which dissolves the middle lamellae considerably in advance of the invasion of the bacteria, but had no action upon the lignified or suberized walls. Brown (1) and Harter and Weimer (4) found that the macerating principle was most active in young and vigorously grown hyphae. The two latter investigators (5) showed, also, that pectinase is present in the spores of *Rhizopus tritici* Saito, and that its development is influenced considerably by the composition and the H-ion concentration of the substratum.

¹ The writer is indebted to Professor R. E. Smith and Dr. J. L. Weimer, for reading the manuscript and for helpful suggestions.

METHODS OF EXPERIMENTATION

The experiments, which follow, were planned and performed in such a way as to demonstrate the hydrolyzing principle of pectinase, obtained from substrata of a different initial H-ion concentration, on onion tissues and pure pectin.

Cultural Methods

The methods for the production of pectinase consisted in growing *Fusarium cromyophthoron* Sid. (10) in onion decoction cultures of a different initial pH, viz., pH of 3.2, 4.0, 5.0, 6.0, 7.0, and 7.5, for different periods and then isolate the enzyme from the substratum. The culture solution was maintained constant in regard to the initial pH with occasional introductions of adjusting reagents, such as 0.2/N HCl and KOH.

The onion decoction was prepared as follows: 200 grams of peeled onions were cut into pieces and boiled in 500 c.c. of water which had been acidified with 25 c.c. of 5/N HCl. The entire mixture was boiled for half an hour and then filtered through cotton. The filtrate was then made up to 1,000 c.c. with a solution containing MgSO_4 2.12 grams, $\text{Ca}(\text{NO}_3)_2$ 0.71 grams, KH_2PO_4 1.36 and $\text{Fe}(\text{NO}_3)_3$ 1 c.c. of a 5 per cent solution, and later adjusted to desired H-ion concentrations.

Twenty-four one-liter Erlenmeyer flasks were employed for the experiment, each one constructed after the apparatus described by Sideris (9). They were divided into four series, each one including six flasks and representing six different H-ion concentrations, viz., pH of 3.2, 4.0, 5.0, 6.0, 7.0, and 7.5. All four series of cultures were inoculated at the same time, but allowed to grow for different periods: Series A, grew for seven days; B, for fifteen; C, for twenty-two, and D, for twenty-nine. The solution was filtered off from the different culture media at the end of each period and the enzyme-containing-filtrate retained while the residue consisted of the mycelial mat of the fungus thrown away.

Isolation of Pectinase

The enzyme contained in the filtrate was used in two different ways for the maceration of onion tissues: One way, was to introduce onion discs directly into the filtrate and observe the action of maceration, and the other, to isolate the enzyme from the filtrate, dissolve it in distilled water and then employ it for the maceration of onion tissues.

The isolation of the enzyme in the latter case was made in the following way: 50 c.c. of the filtrate from each culture were treated with an equal volume of 95 per cent alcohol. The mixture was let to stand for 12 hours; during this time a complete coagulation and precipitation of the enzyme was effected. The coagulated enzyme was recovered from the mixture by

filtration. Hardened filter paper¹ was used for the purpose. The enzyme was then washed from the filter paper into a beaker with distilled water heated to 40° C. The aqueous solution of the enzyme in the beaker was made up to the original volume, viz., 50 c.c., by the addition of distilled water.

BEHAVIOR OF *FUSARIUM CROMYOPHTHORON* IN ONION DECOCTION

The different cultures were inoculated by using sporodochial macroconidia from a pure culture of *F. cromyophthoron*. Germination of the conidia took place in twenty-four hours and a fair growth of the fungus could be observed in the culture media on the fourth day.

The changes in the initial pH of each particular culture, produced by *F. cromyophthoron*, were adjusted by means of reagents, such as 0.2 normal HCl and KOH. The volume of the reagent employed for each culture represents the extent of the changes brought about by the organism. Table 1 contains the volume of the reagent added to each culture and readings of the initial and final pH.

TABLE 1.—*Volume of adjusting reagents required to neutralize the changes produced by F. cromyophthoron in the initial pH of the different cultures of series A, B, C, and D, and readings of the final pH*

Initial pH of series A, B, C, D	Series A Growth 7 days			Series B Growth 15 days			Series C Growth 22 days			Series D Growth 29 days		
	Fin. pH	Reagent H OH		Fin. pH	Reagent H OH		Fin. pH	Reagent H OH		Fin. pH	Reagent H OH	
3.2	3.5	6	0	3.4	12	0	3.0	25	0	3.2	28	0
4.0	4.2	4	0	4.0	9	0	4.0	12	0	4.0	16	0
5.0	5.2	2	0	5.1	5	0	5.0	9	0	5.2	12	0
6.0	6.0	0	4	6.2	3	2	6.1	6	3	6.0	8	5
7.0	7.0	0	10	7.1	0	20	7.1	4	22	7.0	5	26
7.5	7.5	0	16	7.5	0	33	7.5	2	35	7.5	10	40

Explanation of the Results in Table 1

The results indicate that *F. cromyophthoron* is capable of effecting a marked alteration in the H-ion concentration of the external medium, the direction of the change depending upon the initial pH of the medium employed. The volume of the reagent used is an index of the amount of the changes produced by the fungus in each particular case. The seat of the

¹ The hardened filter paper was prepared by treating sheets of a 9 cm. filter paper with concentrated NaOH for two or three minutes, then washing it in distilled water until all traces of the OH-ion were removed.

direction of these changes, *e.g.*, the starting-point for an increase or decrease in the H-ion concentration of the different cultures, lies near or at pH of 5.5. The changes in the initial pH of the cultures ranging between pH of 5.5 and 3.0 were probably produced in two ways: (1) by the reaction of the CO_2 of the fungus on the water of the culture solution, resulting in the formation of CO_3 -ions, and (2) by the reaction of NH_3 released from the hydrolyzed proteins of the onion decoction, on the water of the culture solution, resulting in the formation of NH_4 -ions. The changes, on the other hand, in those cultures ranging in their H-ion concentration between pH of 5.5 and 7.5 were produced by a series of reverse reactions. The organism, like in the preceding case, released CO_2 in the culture solution which reacting with the water formed HCO_3 -ions. Various organic acids may also be formed from the sugars of the onion decoction by the organism and thus alter the initial pII of the culture solution.

Another factor deserving consideration, in this connection, is the age of the culture. This factor is related directly, first, to the period of the utilization of the nutrient substance, and second, to the autolysis of the fungal mycelium. Both phases mentioned influence considerably the changes in the initial pH of the culture. The complete utilization of the nutrient substance may bring an ultimate stop to the metabolic activities of the organism. Autolysis being a kind of protein hydrolysis influences considerably the pH of the culture solution. The HCl added in the cultures of pH 7.0 and 7.5, of series C and D, was for the purpose of neutralizing the NH_3 released from the autolyzing fungal mycelium.

MACERATION OF VEGETABLE TISSUES

The studies on the macerating action of extracellular pectinase were conducted by placing onion discs, one cm. in diameter and three to five mm. in thickness, in Erlenmeyer flasks containing 50 c.c. of the enzymic solution. 20 c.c. of toluol were added in each flask to inhibit biological growth. The flasks were taken in an incubator at 28° C. Observations on the macerating action of the enzyme were made at 2, 3, 4, 7, 10, and 14-day-intervals. The maceration of the discs was estimated on a percentage basis; maceration of the entire disc estimated at one hundred per cent, of the one half at fifty per cent, etc.

The results on the maceration of the discs by the enzyme contained in the original filtrate are recorded in table 2 and those by the enzyme in the semi-purified condition in table 3.

Explanation of the Results in Tables 2 and 3

The results in both tables indicate quite definitely that the H-ion concentration of the substratum and the age of the culture influence consid-

TABLE 2.—Percentage of maceration of onion discs by extracellular pectinase contained in the filtrate obtained from culture solutions of *F. cromyophthoron*, grown at different pH and for different periods

Cultures		Days discs were ex- amined	Macerating action of extracellular pectinase contained in the filtrate of cultures of different pH						
Series	Growth period		pH 3.0	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 7.5	Control
A	7	2	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.
		7	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.
		14	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.
B	15	3	10 pct.	10 pct.	0 pct.	20 pct.	100 pct.	0 pct.	0 pct.
		7	15 pct.	15 pct.	0 pct.	35 pct.	100 pct.	0 pct.	0 pct.
		10	20 pct.	25 pct.	0 pct.	50 pct.	100 pct.	0 pct.	0 pct.
C	22	3	20 pct.	25 pct.	50 pct.	5 pct.	3 pct.	0 pct.	0 pct.
		4	25 pct.	50 pct.	57 pct.	10 pct.	7 pct.	0 pct.	0 pct.
		7	30 pct.	100 pct.	100 pct.	15 pct.	10 pct.	0 pct.	0 pct.
D	29	3	30 pct.	75 pct.	100 pct.	5 pct.	3 pct.	35 pct.	0 pct.
		4	40 pct.	100 pct.	100 pct.	10 pct.	7 pct.	50 pct.	0 pct.
		7	50 pct.	100 pct.	100 pct.	15 pct.	10 pct.	75 pct.	0 pct.

TABLE 3.—Percentage of maceration of onion discs by extracellular pectinase isolated from the filtrate in a semi-purified condition from culture solutions of *F. cromyophthoron* grown at different pH and for different periods

Cultures		Days discs were ex- amined	Macerating action of extracellular pectinase in a semi-purified condition from cultures of <i>F. cromyophthoron</i> of a different pH						
Series	Growth period		pH 3.2	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 7.5	Control
A	7	2	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.
		7	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.
		14	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.	0 pct.
B	15	3	0 pct.	0 pct.	0 pct.	2 pct.	100 pct.	0 pct.	0 pct.
		7	0 pct.	0 pct.	0 pct.	3 pct.	100 pct.	0 pct.	0 pct.
		10	0 pct.	0 pct.	0 pct.	5 pct.	100 pct.	0 pct.	0 pct.
C	22	3	0 pct.	50 pct.	75 pct.	5 pct.	0 pct.	0 pct.	0 pct.
		4	0 pct.	75 pct.	100 pct.	10 pct.	0 pct.	0 pct.	0 pct.
		7	0 pct.	85 pct.	100 pct.	15 pct.	0 pct.	0 pct.	0 pct.
D	29	3	5 pct.	25 pct.	35 pct.	2 pct.	0 pct.	5 pct.	0 pct.
		4	10 pct.	35 pct.	50 pct.	4 pct.	0 pct.	10 pct.	0 pct.
		7	20 pct.	50 pct.	75 pct.	5 pct.	0 pct.	20 pct.	0 pct.

erably the formation and possibly the hydrolyzing action of the extracellular pectinase of *F. cromyophthoron*. It is obvious from both tables that the excretion of extracellular pectinase is favored at certain H-ion concentrations and inhibited at certain others. High concentrations of hydrogen and hydroxyl ions inhibit the excretion and possibly the formation of

extracellular pectinase, to a certain extent. The relatively diminished action of extracellular pectinase at pH of 6.0, shown practically in all series, is rather inexplicable. The writer is of the opinion that the peculiar behavior shown by the organism at this particular pH, *e.g.*, the considerably reduced activity in changing the initial pH of the culture solution, is responsible for the diminished action of the enzyme at this pH. It may be that the irritation which is produced on the fungus by slight concentrations of hydrogen and hydroxyl ions, such as at pH of 4.0, 5, and 7.2, is the cause for the excretion of pectinase at a greater rate than at pH of 6.0.

A comparative study of the results in tables 2 and 3 shows that the macerating action of the enzyme contained in the filtrate was greater than of that in the semi-purified condition. The difference in the activity is undoubtedly due to the loss of the enzyme incurred in the process of purification.

HYDROLYSIS OF PURE PECTIN

The method followed in the preceding experiment for the maceration of onion discs by extracellular pectinase in a semi-purified condition was also adapted for the hydrolysis of pure pectin. The pectin employed for the experiment was furnished by the Department of Food Products of the University of California and supposed to be free from reducing sugars. The quantity of this substance added in each flask, containing 50 c.c. of the enzymic solution, weighed 100 mgms. About 20 c.c. of toluol were added to the solution of each flask to keep it free from biological contamination and all the flasks were placed in an incubator at 28° C.

The determination of the hydrolyzed pectin of each culture was made in the following manner: The solution, containing the enzyme plus the hydrolyzed and non-hydrolyzed pectin, was treated with 10 c.c. of a 1 per cent solution of lead acetate. The Pb-ion coagulates and precipitates the enzyme and the non-hydrolyzed pectin and leaves in solution the hydrolyzed pectin. The solution was heated to 80° C. and then filtered through a hardened filter paper. The filtrate was treated with 5 c.c. of a 2 per cent solution of Na_2CO_3 to remove by precipitation the excess of the Pb-ions and then filtered for the second time. The filtrate, obtained from the second filtration, containing the hydrolyzed pectin was treated according to the method of Munson and Walker for the determination of reducing sugars.

The amount of reducing sugars, in terms of Cu_2O , obtained by the action of extracellular pectinase on pure pectin are recorded in table 4.

Explanation of the Results in Table 4

The results on the hydrolysis of pure pectin by pectinase, in table 4, do not differ essentially from those obtained in connection with the maceration of onion discs in tables 2 and 3. The weight of Cu_2O , representing

TABLE 4.—*Weight of Cu₂O in milligrams expressing the amount of reducing sugars resulted from the hydrolysis of pectin by the extracellular pectinase of F. cromyophthoron, from cultures of a different pH and age*

Cultures			Weight of Cu ₂ O in mgms. representing reducing sugars resulted from the hydrolysis of 10 mgms. of pectin by pectinase in 5 days at 28° C.					
Series	Age	Sample	Pectinase obtained from cultures of different pH					
			pH 3.2	pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 7.5
A	7	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
B	15	1	0.0000	0.0000	0.0000	0.0000	0.0148	0.0080
		2	0.0000	0.0040	0.0000	0.0000	0.0146	0.0072
		3	0.0000	0.0042	0.0000	0.0000	0.0142	0.0060
C	22	1	0.0040	0.0040	0.0046	0.0000	0.0100	0.0050
		2	0.0035	0.0035	0.0040	0.0060	0.0080	0.0042
		3	0.0030	0.0030	0.0036	0.0030	0.0060	0.0036
D	29	1	0.0038	0.0055	0.0146	0.0080	0.0058	0.0170
		2	0.0070	0.0128	0.0170	0.0056	0.0050	0.0149
		3	0.0060	0.0088	0.0150	0.0046	0.0030	0.0160

corresponding quantities of reducing sugars and indicating the extent of pectin hydrolysis, is analogous to the percentage of maceration expressed in the preceding experiment. The behavior of pectinase, in its relation to the pH and age of the culture, is the same in both experiments.

There is no definite knowledge on the nature of the products obtained from the hydrolysis of pectin. Considerable experimentation proved that substances such as galactose, arabinose, methyl alcohol, and acetone may all be products of pectin hydrolysis. The writer obtained negative results in an experiment in which the presence of galactose in a solution of hydrolyzed pectin was tested by the mucic acid method.

GENERAL DISCUSSION

The behavior of *F. cromyophthoron* in its relation to the excretion of extracellular pectinase varied with the age of the culture and the H-ion concentration of the substratum. The macerating action of extracellular pectinase of relatively young cultures, viz., seven days old, on onion discs and pure pectin was practically nil. This behavior may be explained in two different ways: first, that pectinase does not form in relatively young cultures, and second, that if it forms it is impervious to the cell walls of very young hyphae. The excretion of pectinase, constantly found associated with older cultures, is possibly due to the increased permeability

of very old and dead cells of the fungus. It is not known whether the permeability or impermeability of the cell membrane of young hyphae is related to any extent to the saprophytic or parasitic qualifications of an organism.

The rapid release of pectinase at pH of 7.0 is possibly due to the properties of the hydroxyl ion, while the slow release at pH of 5.0 and 4.0 to the properties of the hydrogen ion. According to Osterhout (7, 8) low concentrations of hydrogen ions decrease the permeability of cell membranes, while concentrations of M .001 of NaOH increase it. The relatively small proportions of pectinase released at pH of 3.0 and 7.5 are due to the toxic properties of high concentrations of hydrogen and hydroxyl ions, which probably intercept the normal behavior of the organism. It is possible that the organism under adverse conditions may not form the same metabolic products which would otherwise under normal conditions.

The chemical reactions taking place between the pectinase and its substratum, *e.g.*, the onion discs or the pectin, are but slightly understood. This is due undoubtedly to our meagre knowledge of the molecular constitution of both the enzyme and the pectin. The chemical nature of pectin has been studied by Fellenberg (3) who found that pectin hydrolyzes in the presence of a small excess of alkali. Tutin (11), in studying the products of pectin hydrolysis obtained from the action of pectinase on pectin and from the action of alkalis found that in both cases methyl alcohol and acetone were produced. Clayston, Norris and Schryver (2) state that pectin, unless highly purified, is not a single chemical substance but a mixture of such substances. They found that by treating pectin-containing substances with a certain concentration of NaOH, methyl alcohol and some other substances resembling hemicelluloses in their reaction, named "cytopentans" for convenience, were produced. The alkaline extract containing the methyl alcohol and cytopentans did not hold in solution any pectic substances; the latter, could be extracted from the residues with warm ammonium oxalate solution followed with HCl, the acid precipitating the pectin in the solution. Therefore, the methyl alcohol and acetone obtained in the hydrolysis of pectin by Tutin, may not result from pure pectin but from other compounds.

SUMMARY

The pectinase of *Fusarium cromyophthoron*, contained in the filtrate obtained from liquid media of different H-ion concentrations and growth periods, was used for the maceration of onion discs and the hydrolysis of pure pectin. The enzyme was used, in certain experiments, in the condition it existed in the original filtrate, and in others, in a semi-purified condition. The macerating action of the enzyme was found to decrease with purification.

In relatively young cultures the action of extracellular pectinase was found to be nil. In older cultures the action of extracellular pectinase was detected practically in every culture.

The amount of pectinase, measured by its action, secreted in the different cultures varies with the age of the culture and the H-ion concentration of the substratum. The age of the culture, affecting the longevity of the cells, influences considerably the permeability or impermeability of the cells of the fungus to pectinase. The hydrogen and hydroxyl ions, likewise, influence the rate of pectinase excretion.

Reducing sugars were obtained from the hydrolysis of pectin by pectinase. Tests for galactose gave negative results.

LITERATURE CITED

1. BROWN, WILLIAM. Studies in the physiology of parasitism. I.—The action of *Botrytis cinerea*. Ann. Bot. 29: 313-348. 1915. References, p. 348.
2. CLAYSON, D. H. F., F. W. NORRIS and S. B. SCHRYVER. The pectic substances of plants. Pt. II.—A preliminary investigation of the chemistry of the cell-walls of plants. Biochem. Jour. 15: 643-653. 1921.
3. FEELLENBERG, TH. VON. Über die konstitution der pectinkörper. Biochem. Zeitschr. 85: 118-161. 1918.
4. HARTER, L. L., and J. L. WEIMER. Studies in the physiology of parasitism with special reference to the secretion of pectinase by *Rhizopus tritici*. Jour. Agric. Res. 21: 609-625. 1921. Literature cited, p. 624-625.
5. ————. Influence of the substrate and its hydrogen-ion concentration on pectinase production. Jour. Agric. Res. 24: 861-878. 1923. Literature cited, p. 877-878.
6. JONES, L. R. The bacterial soft rots of certain vegetables. II.—Pectinase the cytolytic enzyme produced by *Bacillus carotovorus* and certain other soft-rot organisms. Vermont Agric. Exp. Sta. Bull. 147: 281-360. 10 fig. 1909. Bibliography, p. 357-360.
7. OSTERHOUT, W. J. V. The effect of alkali on permeability. Jour. Biol. Chem. 19: 335-343. 1914.
8. ————. The effect of acid on permeability. Jour. Biol. Chem. 19: 493-501. 1914.
9. SIDERIS, C. P. An apparatus for the study of microorganisms in culture solutions under constant H-ion concentrations. Science, 60: 17-19. 1924.
10. ————. Species of *Fusarium* isolated from onion roots. Phytopath. 14: 211-216. Pl. 9-11. 1924.
11. TUTIN, FRANK. The behavior of pectin toward alkali and pectase. Biochem. Jour. 15: 494-497. 1921. References, p. 497.

A DISEASE ON AMARANTUS, CAUSED BY CHOANEPHORA CUCURBITARUM (B. & RAV.) THAXTER

B. T. PALM AND S. C. J. JOCHEMS

WITH PLATE XXVIII

Choanephora Cucurbitarum (B. & Rav.) Thaxter has a wide distribution in the tropical and subtropical parts of the New and Old Worlds. Its occurrence in South America (Brazil) has been recorded by Möller (1921) as *Ch. americana* Möller; its distribution in North America (U. S. A.) by Wolf (1917); and in Asia (British India) by Dastur (1920). As is well known, *Ch. cucurbitacearum* not only lives saprophytically on rotting plant material, but also causes characteristic diseases on a number of plants. It attacks living flowers of *Hibiscus Rosa sinensis* L. and of other members of the same family as well as of the Cucurbitaceae family (Möller, Wolf); further it causes a not unimportant disease in the fruits of *Cucurbita pepo* (Wolf), and on species of *Capsicum* (Dastur).

By reason of its interest from a phytopathological point of view, we wish to put on record here a new disease caused by *Choanephora Cucurbitarum* in Sumatra, i.e., on *Amarantus Blitum* L. Two other species of *Choanephora* have recently been reported from the Dutch East Indies by Gandrup (1923), viz., *Ch. infundibulifera* (Cunn.) Sacc, and *Ch. dichotoma* n. sp.; the latter as yet without diagnosis.

Amarantus Blitum is not without importance as a substitute for *Spinacia oleracea* L. and *Portulaca oleracea* L., the culture of which apparently is difficult in tropical lowlands. This *Amarantus*—in the Malayan tongue “Bajam,” under which name it is known also to the Europeans here—is, however, not cultivated, but simply collected from lands lying fallow, where it grows in abundance. Like most weeds in Sumatra of relatively recent introduction, it is remarkably free from parasitic fungi; till now only *Cystopus Bliti* has been observed.

When visiting a tobacco estate, situated about 50 miles above sealevel, in May, 1923, we found some specimens of “bajam” that showed an interesting disease. It is perhaps worth mentioning here that the locality was a shallow valley with a rivulet where the tobacco had died early in the season from a wilt disease (caused by *Bacterium Solanacearum* EFS) with the result that the usual growth of weeds had had an opportunity to develop luxuriantly. Half of the weed vegetation consisted of *Amarantus Blitum*; on closer inspection practically every “bajam” plant, and indeed every branch, showed the disease. Later we found the disease in the entire tobacco district of the East coast of Sumatra, on different kinds of soil,

and at different heights above sealevel. Perhaps the abnormally high humidity (for this time of the year) that prevailed in June and July this year have contributed to its wide distribution.

THE DISEASE

The disease on the "bajam" shows more or less uniformly the following symptoms. Generally the young diseased branches show a rather sharp bend, at 5 to 10 cm. from the top of the shoot (Plate XXVIII, fig. 1). From this point upwards and downwards the stem is blackened or of a dark brown color. In comparison with the undiseased portions, the stem is harder, but at the same time extremely brittle. The leaves, of the diseased parts generally hang limply, having lost their turgescence. The infected organs do not show the "wet rot" that is said to be so characteristic of the Choanephora diseases of *Cucurbita pepo* (Wolff) and *Capsicum* (Dastur). However, a wet rot may be found during very humid weather, but in that case the Choanephora seems always to be accompanied by an undetermined species of *Fusarium*; presumably the rotting is caused by the latter fungus.

In the early morning hours newly diseased organs carry a heavy crop of the characteristic conidiophores of Choanephora (Plate XXVIII, fig. 2). As already observed by Cunningham (1879) for *Ch. infundibulifera* (Cunn.) Sacc. and for our species by Möller, the conidal fructification develops only at night or during the earlier hours of the morning; this we found also to be the case in Sumatra. Sporangial fructification was only relatively seldom met with on diseased parts.

When diseased plants are collected at noon or later in the day, generally rather scanty traces of the Choanephora fructification are to be found. On the second or third day after infection has taken place there is seldom much, if anything, of the fungus to be seen, the diseased parts being practically smooth, with the exception perhaps of portions of diseased leaves.

It is said, that the infection in all diseases, caused by a Choanephora, starts in the newly opened flower. While this may be true also for the disease on *Amarantus*, we have not seen any evidence of such a mode of infection; our observations tend to show that the fungus may enter through other organs as well. The following infection experiments will confirm this.

As infection material we used a pure culture of Choanephora from *Amarantus Blitum*, grown on boiled rice. This culture was the third reiso-lation from our first culture, also on boiled rice.

Experiment I. Ten young "bajam" plants were used for inoculation with a small tuft of sterile mycelium; 5 specimens were slightly wounded by a scalpel (set A), the 5 others not injured (set B). Next day 2 speci-

mens of set A showed the typical symptoms of the disease over about 5 cm. of the stem (Plate XXVIII, fig. 3) ; after 2 days 2 more plants of the same set became diseased. Of set B no plants had signs of infection after 5 days.

Experiment II. Nine young "bajam" plants were infected with a suspension of conidiospores from the above mentioned pure culture, care being taken not to wound the infected spot in any way; set A (5 plants) on the upper side of the leaf, set B (4 plants) on the underside of the leaf. In set B, after 2 days, 1 plant showed signs of the disease and after 3 days 2 more plants succumbed; set A showed no results from the infection.

Experiment III. Here the underside of the leaves of 4 plants were infected, with small tufts of mycelium without wounding, the result was that after 2 days 1 plant was infected, after 3 more days all of the successful infections in these experiments resulted in the characteristic drooping of the diseased stems. These few experiments tend to show that slight wounding facilitates the infection, and further that an infection can as easily take place through the unwounded underside of a leaf. Precisely how the infecting mycelium penetrates, we did not ascertain.

In two cases this disease was found on another species of *Amarantus*, *A. spinosus* L. In both instances the two *Amarantus* species were growing intertwined, causing direct contact between diseased portions of *A. Blitum* with leaves or branches of *A. spinosus*. The symptoms resembled closely those recorded for *A. Blitum*.

Not infrequently we found black spots on the young upper leaves of *Synedrella nodiflora* (Family Compositae) associated with a bending over of the branches (Plate XXVIII, fig. 4). In one case similar symptoms were found on leaves and branches of another species of the Compositae, *Eleutheranthera ruderalis* L. The cause of the trouble was in both instances the *Choanephora* in question.

However, Möller has already found that in nature *Ch. Cucurbitarum* is not necessarily restricted to a living substratum; he recorded finding the fungus on rotting plant debris. Sometimes we have collected the conidial stage of a *Choanephora* that apparently belong to *Ch. Cucurbitarum* on dead or wilting stems of *Physalis* sp. that had been uprooted when weeding the tobacco fields for the coming rice crop. Infection experiments were, however, not undertaken.

THE CAUSATIVE FUNGUS

All authors who have studied the species of *Choanephora* in their natural habitat agree that only conidiophores are developed; when taken into culture, the other fructifications are formed more or less constantly. On *Amarantus Blitum*, however, in a number of instances, well developed sporangiophores have been met with on diseased parts of the plant in the

field. They seem to occur by preference on older infections intermingled with the conidial fructification. In our cultures, we invariably got both kinds of fructification, the conidial one always developing first.

These sporangiophores are, so far as we have seen, shorter and stouter than the conidiophores. They show the usual bend with its slight thickening beneath the sporangium, already noted by Möller. The darkly colored sporangia which thus are forced into a pendant position contain an average of about 100 spores. When breaking open, the sporangial wall generally splits into two halves, leaving at the base of the columella a plainly visible collar. Möller describes the sporangial wall as dark colored and finely sown with minute granulations; according to Dastur it should be smooth and colorless. For the species on *Amarantus* we found Möller's description confirmed. The spores from the sporangia show quite the same measurements as the conidia, *i.e.*, when compared with conidia from the same infected area. It seems worth while to mention that sporangiophores, produced in situ from parasitical mycelium in the plant regularly showed a somewhat onion-like swelling at the base, much in the same way as some *Peronosporas* and *Sclerosporas*. Möller has described a similar condition for conidiophores developed on infected parts; he found, however, that no basal swellings developed from a mycelium in artificial cultures. Wolff (*l.c.*, pl. 85, fig. 1) also gives a figure of a sporangiophore, from a pure culture, without any basal swelling.

The spores from the sporangia are provided with the characteristic hyaline appendages of about the length of the spore, are non-striated and agree completely with the description given by Wolf for *Choanephora Cucurbitarum* (B. and Rav.) Thaxter.

This is also the case with the conidia; *i.e.*, the dark violet color, the oblong form, the striation, the hyaline stump at the base as well as the size; they measure from 14 to 25 μ in length and from 8 to 12 μ in diameter.

In our cultures on boiled rice, chlamydospores of various sizes and shapes were seen; no zygospore formation has taken place as yet.

The shape of the columella is given as globular in all species. Möller (*l.c.*, p. 21) says: "Bei allen auch ist eine kuglige Columella vorhanden," Wolff and Dastur also agree on this point. Only Wolf pictures the columella as globular, the drawings published by Möller and Dastur show the columella plainly pearshaped and twice as long as broad. In the *Choanephora* on *Amarantus* the columella is rather variable in shape; from globular to pearshaped having been noted. The shape of the columella in the genus *Mucor* having been made the basis of classification, we have thought it useful to direct attention to this variability here. In view of the existing discrepancies between the different authors regarding size and form of the conidiophore in what is regarded as one species, a comparative

cultural study of the *Choanephora* from different sources should prove valuable in clearing up definitely the value to be attached to the species-characters as present accepted for the genus *Choanephora*.

LITERATURE CITED

- CUNNINGHAM, D. D. On the occurrence of conidial fructifications in the Mucorini, illustrated by *Choanephora*. Trans. Linn. Soc. Bot. London (ser. 2 5: 409-422, pl. 47. 1879.
- DASTUR, J. F. *Choanephora Cucurbitarum* (B. & Rav.) Thaxter, on Chillies (*Capsicum* spp.). Ann. Bot. 34: 399-403, pl. xix. 1920.
- GANDRUP, J. Onderzoekingen over het optreden van dufheid in tabak. (Investigations on the occurrence of mustiness in tobacco.) Besoekisch Proefstation Meded. 35. 1923.
- MÜLLER, A. Phycomyceten und Ascomyceten. Untersuchungen aus Brasilien. 319 p., xi pl. Jena. 1921.
- WOLF, F. A. A squash disease caused by *Choanephora Cucurbitarum*. Jour. Agric. Res. 8: 319-327, pl. 85-87. 1917.



CHOANEPHORA CUCURBITARUM ON AMARANTUS

FIG. 1. A specimen of *Amarantus Blitum* L. attacked by *Choanephora Cucurbitarum* (B. & Rav.) Thaxter, with characteristic symptoms. (Half natural size.) FIG. 2. Conidiophores of *Choanephora* on diseased branch. FIG. 3. One-day-old artificial inoculation of young plant (*A. Blitum*; reduced size). FIG. 4. Diseased specimen of *Synedrella nodiflora* L. (Half natural size.) *

TYLENCHUS DIPSACI KÜHN ON NARCISSUS

C. E. SCOTT

WITH PLATE XXIX AND THREE FIGURES IN THE TEXT

INTRODUCTION

Narcissus bulbs have been successfully propagated on the Pacific Coast for a number of years. Commercial bulb growing in California is largely confined to the rather narrow section that comes under the modifying influence of coastal climatic conditions. The planting of narcissus bulbs has been greatly increased during the past season and the industry is receiving more attention than it has in the past. One of the troubles to be feared by the grower is the injury caused by the bulb nematode, *Tylenchus dipsaci* Kühn. This has been known as the "old disease," "celworm disease of narcissus" and sometimes just as the "narcissus disease."

DESCRIPTION OF THE DISEASE

Under the conditions in California during the past season it has been found that the nematode injury was most apparent in the leaves and flower stems after the end of the blossoming period. At this time the severely diseased plants are much stunted, showing only half the leaf growth of healthy bulbs. These leaves are prostrate on the ground or nearly so, and in contrast to the erect habit of healthy plants except in Paper White narcissus, the thin leaves of which have a natural tendency to mat down slightly after they flower. The nematode causes a distortion of the leaves and stems. Such leaves may be twisted, with irregular margins, but the characteristic thickened specks or "spikkels," as they are called in Holland literature, are always present. To distinguish these "spikkels" from other injuries that are often found in the fields, the leaves should be drawn between the fingers. Nematode spots have the feeling of a lump that is entirely in the tissues of the leaf or stem and never on the surface. The injury may be nearer one side of the leaf but can be felt from both surfaces. The tissue of the leaf over the center of the "spikkel" may dry out, crack and become brown in color. A light yellow area surrounds the small brown spot. The slightly yellowed prostrate leaves, twisted and with irregular margins, are searched for when inspecting bulb fields for *Tylenchus dipsaci*. However, the thickened "spikkels" are the one positive evidence of the nematode disease.

When bulbs bearing strongly injured leaves are cut across, the characteristic brown ring will be revealed. Early in the season the ring will be seen as a thin brown line. This represents the layer that was infested last

season and in which the nematodes were active while in storage. After planting bulbs that are in this condition, some nematodes make their way to the new leaves of such bulbs and some to the soil. This method of spread is clearly followed in plantings of bulbs in ground which has not been previously planted to any variety of narcissus and where the bulbs have been in only during the current season. It is common to find one badly diseased plant and a half dozen plants on either side showing the leaf specks only. Figure 1 shows a group of *Victoria narcissus* in the same relative position as they were in the ground. The bulb in the center, bearing one small deformed leaf was responsible for spreading the disease. The nematodes have infested the two bulbs on either side. The leaves of these plants are twisted, thickened and yellowed. The leaves on the other bulbs are nearly normal in length but were found to have numerous "spikkels." Such local infestations may extend to adjacent rows at a distance of fifteen or twenty inches. Sometimes the bulb that was responsible for such an infested area will have failed to make any top growth, but will have thrown out a few roots. All degrees of infested plants will be found up to those that have made a nearly normal top growth, but showing a few "spikkels."

INJURY TO THE BULB

Upon examination of the bulb that shows severe injury in the top growth at the end of the season, one or more brown rings will be found. At first, the ring or part of the ring is but slightly discolored. As the nematodes increase by the invasion from diseased leaves and by reproduction, the brown color becomes distinctive. The diseased ring retains the normal thickness and the nematodes remain active in the tissue throughout the storage season. No evidence has been obtained to show that the nematode has the ability to pass from a diseased scale to a healthy scale adjacent to it. It is apparent that infection occurs only through the very young leaf as it pushes through the soil and the nematodes pass from that leaf to the corresponding leaf scale. However, it often happens that all the leaves of a bulb become so diseased that every scale is finally invaded.

The presence of the nematode can be demonstrated in the field by using material from a diseased bulb. A bit of diseased tissue may be put in a drop of water on a piece of glass and examined with a hand lens. An inexperienced person may readily see the active adults, and the eggs and larvae can be distinguished with but little trouble. Under favorable conditions the adults may be seen in the leaf tissue, with a hand lens, when a "spikkel" is broken, not cut across. Adults, larvae and eggs of *Tylenchus dipsaci* will be found to be numerous in the brown rings of diseased bulbs. They are present in great numbers even when only the slightest discoloration can be discerned. The nematode is not so abundant in the "spikkels" particularly

when they first appear. At that time it is common to find only a few adults in a characteristic "spikkel." Bulbs will commonly be found that have brown rings caused by insects or mites. These may be distinguished by examining a bit of the diseased tissue with the aid of the hand lens or noting the condition of the leaves with respect to "spikkels."

METHOD OF SPREAD

The nematode disease has been found in stock that has been propagated in California for twelve years, as well as in bulbs growing there in their first season from Holland, on clean land. The bulb nematode was found to have spread to an alarming extent in fields that were left without digging for two or more years. Diseased spots in these fields extend for a greater distance along the length of the rows than across the rows. Some spots included two or three rows and extended for a distance of four or five feet. One diseased area in a field of Paper White narcissus that had been in place for two years, covered five rows at the widest place and a distance of about thirty feet along two rows. This points to the hand cultivators as being an important factor in spreading the nematode in the field. It seems probable that the nematode would spread less rapidly where bulbs are grown in the Dutch bedding system. The weeding is necessarily done by hand and infested soil or diseased bulbs and leaves will not be so readily scattered. Most of the bulbs in California are grown in single rows about fifteen inches apart. This allows the use of hand operated cultivators and weed cutters.

The source of infection of a field may be judged from the conditions of the "spikkels" and appearance of the bulbs when cut. Bulbs with severely twisted leaves, and showing one or more brown rings when cut during the early part of the growing season, were diseased when planted. Such bulbs become worthless and spread nematodes to the soil and other bulbs. When healthy bulbs are planted in infested soil or near diseased bulbs, nematodes invade the young leaves and produce "spikkels" and slightly twisted leaves. Such bulbs will be free from brown rings during the early part of that growing season. We have then three types of injury that will be found when diseased bulbs remain in the ground. This was seen in a field of Emperor narcissus that have been in place for twelve years. The bulbs were dead in the center of the infected area. This spot was bordered by a ring of plants which were stunted and dwarfed. Beyond this circle were the leaves of normal length but twisted and thickened. From this type the infection graded out to leaves bearing only one or two "spikkels" and with the bulbs showing no brown rings when cut (See figure 1).

CONTROL

For the control of the disease the first action that is recommended is the destruction of all diseased plants. Since the disease can be recognized best

in the growing plants, such work must be done in the field. When it occurs in a few scattered spots in the field it is practical to rogue out the plants that show nematode injury. On the other hand, the infestation may be so severe that the eradication of the diseased bulbs would not be practical. A method of treating diseased bulbs by immersion in water at a temperature

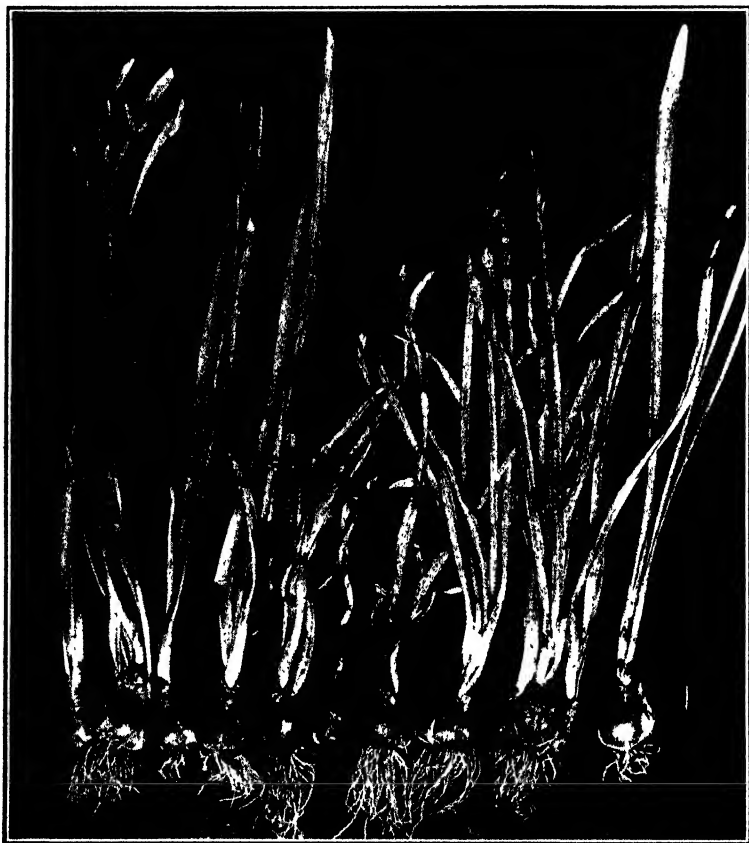


FIG. 1. *Victoria narcissus* photographed in same relative position in which they grew in the field. The central bulb was diseased when planted. The nematode spread to the two adjacent bulbs which produced twisted leaves. The other bulbs produced leaves with spikkels, but normal in size and with no twisting.

sufficient to kill the active nematodes and without injury to the bulbs has been developed in Holland and is used on the more valuable varieties. Van Slogteren¹ has been successful in the use of water at 110–111° Fahrenheit

¹ Van Slogteren, E. *De Nematoden-Bestrijding in de Bloembollenstreek*. Wageningen, 1920.

for three hours. This temperature is sufficient to kill the nematodes that have not dried out. As the bulbs stand in storage under dry atmospheric conditions some of the nematodes in the outer scales dry out and in that condition they are able to resist the temperature of 110° Fahrenheit. On this account the best time for treatment would be immediately after digging, but the greatest injury to the bulb from the hot-water treatment may result at that time. Our problem then is to determine how soon after digging can the bulb be safely given the treatment.

Preliminary experiments made during the past season indicate the possibility of developing a method that will give good control under our local climatic conditions.

METHOD OF TREATMENT

Two lots of bulbs consisting of 590 Paper White narcissus and 374 Emperor daffodils were used in a test of the hot-water treatment on August

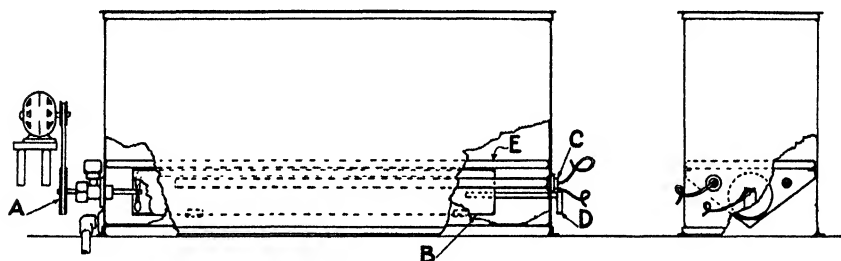


FIG. 2. Drawing of vat used for hot-water treatment of bulbs. Side view shows "A," Circulating propeller—"B," Tube to direct the flow of water and maintain circulation in all parts of the vat—"C," Electric heating elements (2) with capacity of 2.4 kilowatts at 220 volts—"D," Thermostat tube—"E," Removable screen bottom. End view shows relative positions of heating elements, thermostat tube, circulating tube and V-shaped bottom which facilitates cleaning and draining. Capacity of vat is 17 cubic feet. Designed by H. Stiner, California State Department of Agriculture.

30th. The Paper Whites had been allowed to cure in the ground and then were dug on the 18th of June. The Emperors were grown under very different climatic conditions, as they were not completely cured when removed from the ground about the first of August. Both varieties were stored under dry conditions until the time of treatment. The bulbs were sorted before treatment and all that were soft or damaged were discarded. They were further sorted according to size, the large bulbs ranging in weight from 20 to 70 grams, and the small bulbs, including splits, weighing from about 5 to 20 grams, were handled separately for one, two- or three-hour exposure to 110° Fahrenheit in warm water.

The water was heated by electric immersion units, thermostatically controlled and kept in vigorous circulation by a motor driven propeller in a vat measuring 62 inches long, 17 inches wide and 24 inches deep (Fig. 2). The water was maintained at a temperature of about 43.6°C. (110.5°F.) during the major part of the treatment, and varied between 43.2°C. (109.8°F.) and 43.8°C. (110.8°F.) Wire and wicker baskets measuring about one foot in diameter were used as containers. The bulbs were planted after treatment in unsterilized soil that was assumed to be free of *Tylenchus dipsaci*.

The green tops of the bulbs were inspected at the close of the flowering period for the presence of nematode injury. A tabulation was made which included the number of diseased plants, leaves and flower stems. These results are included in table 1. The degree of infestation was not recorded in this table.

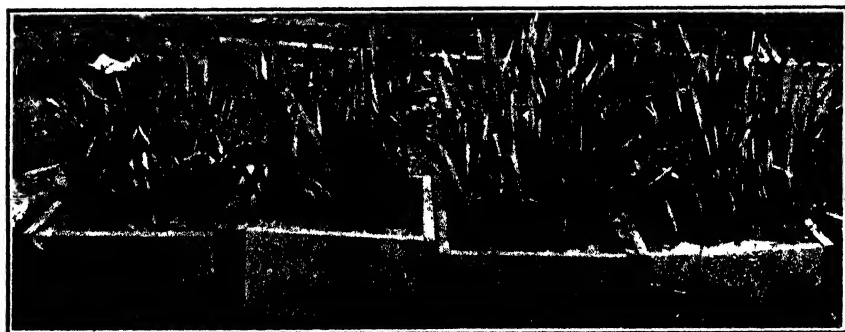


FIG. 3. Emperor narcissus photographed at the end of the blossoming period. Box XIII untreated. Box XIV treated one hour. Box XV treated two hours. Box XVI treated three hours in hot water at 110° Fahrenheit.

From these results it is apparent that a record of the severity of infestation after treatment is a better index of the effectiveness of the treatment than the actual count of diseased leaves and flower stems indicate. This point is brought out both in the Paper Whites and Emperors. Box VIII (Table 1) had approximately the same number of diseased leaves as the untreated lots. But an examination of the Paper Whites toward the end of the growing season shows that the tops of the bulbs in Box XII are greener and more vigorous than the others.

The treated Emperors show a decided reduction in the number of diseased leaves. The appearance of the growing plants point decidedly toward the effectiveness of hot-water treatment. The four boxes, XIII, XIV, XV and XVI are reproduced in figure 3. These boxes were examined on the

TABLE 1.—Results of hot water treatment on narcissus bulbs infested by *Tylenchus dipsaci*

Box number	Variety	Size	Treatment	Bulbs planted	Plants diseased	Number of leaves	Leaves diseased	Number of flower stems	Flower stems diseased
I	Paper White	large	untreated	50	40	322	448	36	23
II	Paper White	large	untreated	50	38	395	367	22	21
III	Paper White	large	one hour	50	37	538	321	34	16
IV	Paper White	large	one hour	49	36	456	232	24	12
V	Paper White	large	two hours	50	31	602	208	43	8
VI	Paper White	large	two hours	50	26	607	63	33	6
VII	Paper White	large	three hours	50	13	515	17	38	4
VIII	Paper White	large	three hours	50	50	525	450	31	26
IX	Paper White	splits	untreated	65	27	275	81	7	5
X	Paper White	splits	one hour	40	28	210	102	8	4
XI	Paper White	splits	two hours	40	20	238	55	16	4
XII	Paper White	splits	three hours	40	26	123	106	7	3
XIII	Emperor	large	untreated	32	26	161	115	22	6
XIV	Emperor	large	one hour	24	18	130	55	10	1
XV	Emperor	large	two hours	30	25	148	65	20	1
XVI	Emperor	large	three hours	48	35	236	75	34	0
XVII	Emperor	splits	untreated	24	16	80	31	2	1
XVIII	Emperor	splits	one hour	26	3	76	8	1	0
XIX	Emperor	splits	two hours	41	27	158	62	9	0
XX	Emperor	splits	three hours	42	35	135	95	2	0

first of June and it was found that there were green tops on only four plants in Box XIII, five in Box XIV, twelve in Box XV and twenty in Box XVI. The diseased leaves had withered and died down prematurely. The appearance of the untreated lot in Box XIII at this time are shown in plate XXIX, fig. E. Judging from the results obtained in these preliminary tests, we expect to get good control of the bulb nematode by treatment soon after digging.

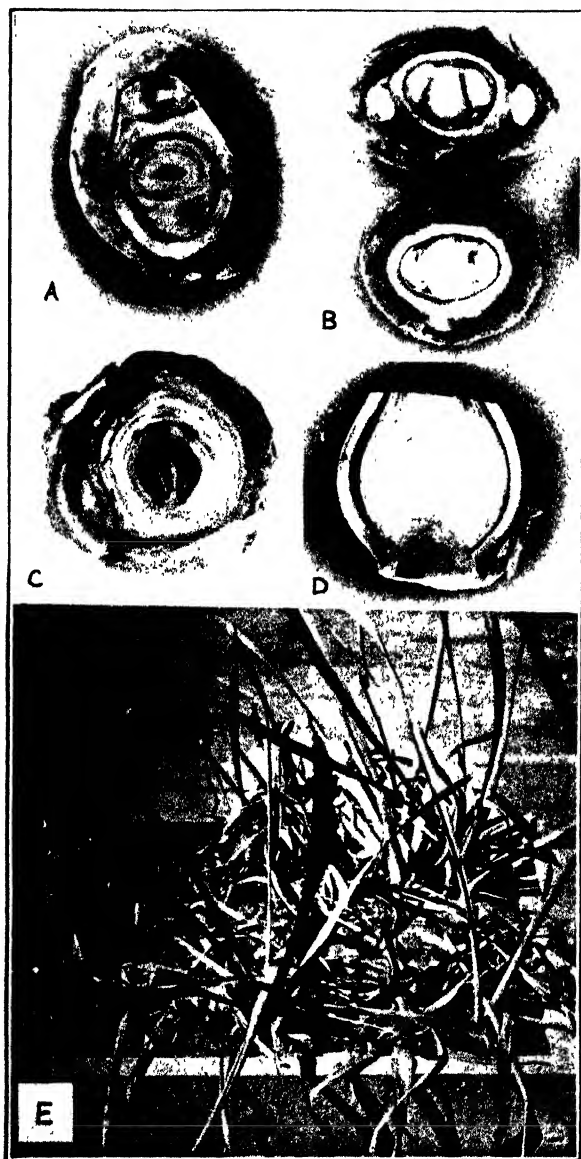
SUMMARY

Tylenchus dipsaci Kühn causes a serious disease of narcissi. Characteristic "spikkels" are formed in the leaves and flower stems which serve to identify the disease in the field. Severely infested leaves which are stunted and twisted die prematurely. The nematodes invade the bulb scales from the corresponding leaves and kill the tissue. When diseased bulbs are planted, nematodes make their way to the soil and to the young leaves as they push through the ground. Control measures that are recommended are the destruction of the diseased plants in the field and bulb treatment. Treatment of bulbs in hot-water at 110° Fahrenheit for three hours is the most promising method. Tests are being made to determine the period during which this treatment will be most effective, and will result in the minimum injury to the bulb.

CALIFORNIA STATE DEPT. AGRIC.

EXPLANATION OF PLATE XXIX

FIG. A. Paper White bulb showing narrow brown ring encircling the old bulb and two new infections. The flower stem photographed dark but was not diseased. FIG. B. Paper White bulbs that were infected when planted. FIG. C. Severely diseased bulb that was probably free from nematodes when planted. FIG. D. Vertical section of Paper White bulb showing nematode ring extending to the bulb stem. A, B, C, and D were dug and photographed after the flowering period and while the leaves were still green. FIG. E. Emperor narcissus, untreated Box XIII. This shows the premature dying of leaves badly attacked by *Tylenchus dipsaci*. Compare with figure 3, taken earlier in the season.



TYLENCHUS DIPSACI ON NARCISSUS

THE PHYTOPHTHORA DISEASE OF LILAC

HELENA L. G. DE BRUYN

WITH SIX FIGURES IN THE TEXT

INTRODUCTION

In the years 1913 and 1919 much harm was done to the lilac culture in Aalsmeer by the fungus *Phytophthora syringae* Kleb. by killing the buds and parts of the branches of the lilacs being made ready for forcing in winter. It is only in this form, occurring from January to March, that any measurable harm is done to the plants. The buds situated under the diseased part develop normally. The result will be, that if some lower branches of ordinary lilac bushes are attacked during winter, the dead ones will soon be replaced by the new developing buds in spring. For the purpose of forcing it is a quite different thing. Only a dozen branches are left on a low stem and the plants are used for forcing from November till April. The branches are long and thick and if either the buds and upper part or some other part is killed, the whole branch loses its value.

In many years not a single diseased bud was to be found, in others only a few cases were observed, while in the two years mentioned above a real epidemic occurred causing great loss to the cultivators.

The lilac trees are forced each second year, but even in the year they are not used for forcing they are pruned. If the *Phytophthora* should remain living in the stem, in any form whatever, the first part of the branch to be diseased should be that near the stem. The contrary is often the case, the upper parts being the first to show the disease. This and the fact that in most years diseased branches are totally absent, prove that each affected part corresponds with a new infection coming from outside.

This research was undertaken to gather some more exact knowledge about the time when infection really takes place, thus hoping to find some means of preventing new epidemics. Since the beginning of the work in the spring of 1920, circumstances have not been favorable for the attack of the branches by the fungus. Not even a dozen diseased ones could be gathered during all those years. It was therefore impossible to test the theories by the facts in nature. Still it was thought advisable to publish the results as through the experiments and observations new facts were established which might make it possible to prevent in future the outbreak of a new epidemic.



FIG. 1. *Syringa* leaf affected with *Phytophthora syringae*.

FIG. 2. Bud inoculation. The three upper buds are killed.

FIG. 3. The same branch as figure 2 a fortnight later. Buds of the third node developing normally. The disease makes no further advance after the buds start growth.

FIG. 4. Dark affected leaf trace; the fungus remains alive here until it can enter the cortex.

SYMPTOMS OF THE DISEASE

The occurrence of diseased lilac buds was first noticed by Klebahn (4) in 1905 in cultivations of forced lilacs near Hamburg. The fungus causing the disease was named by Klebahn (5) *Phytophthora syringae*. In this last paper he gives a full description of the outer symptoms of the diseased branches.

Buds and cortex are killed, which is to be observed by the brown coloring of both and by some shrinking of the cortex. When used for forcing, the non-development of the buds is another sign. Oospores may be present in the brown tissue of the bud scales as well as in that of the cortex and are distinctly visible after decolorizing the tissues with caustic potash.

According to Klebahn the different varieties of lilac are attacked in different ways. Of some varieties the upper parts of the branches are mostly killed, while in others the lower internodes are especially affected. In this last case the normal development of the higher buds is often prevented, especially if the killing of the cortex has gone so far that girdling of the stem takes place, preventing the normal flow of sap. In some cases two or more places of infection on the same branch can be observed, two or more diseased brown parts of the branch being separated by a green healthy piece. For the varieties of lilac used in Holland the difference of attack was described by Schoevers (10). Both authors, however, mention that the differences are not constant and that intermediate stages occur. Through the lack of occurrence of diseased branches in nature the difference of attack of the various varieties could not be studied by the writer nor its reason, which might be partly due to the different habitats of the lilac plants. The different varieties show some more or less spreading of the branches and difference in length.

It was, however, found that *Phytophthora syringae* not only attacked the buds and branches of lilacs, but that the fungus can also affect the leaves. This form of the disease does not seem to have been observed by Klebahn. On the leaves the fungus causes brown patches, which are irregular in outline, increasing gradually and occurring at any place independent of the nervature. (Fig. 1.) At the margin of the brown patch a lighter zone is observed. The color of the spots is distinctly brown, darker with the blue varieties, and always lacking the olive-green color, which is characteristic for the attack of *Heterosporium syringae* Oud.¹ (5). The affected leaves were really found in nature even at different times of the year, but only after a certain period of moist weather. *Phytophthora syringae* could be easily isolated in pure culture from them. Lilac branches inoculated in winter with *Phytophthora* isolated from affected leaves showed the same

¹ According to Arnaud (1) we have here to do with a *Cladosporium* and not with a *Heterosporium*.

symptoms as those inoculated with *Phytophthora* isolated from diseased branches.

On affected leaves, still wet with dew, sporangia were observed, proving that sporangia do occur in nature. They are very short stalked and emerge singly or in small clusters through the stomata (Fig. 5) both on the upper and lower side of the leaf; the majority, however, occurring on the lower side. They are not easily seen by the naked eye as a white haze, as is the case with *Phytophthora infestans*. In the inner part of the brown tissue of the leaves oospores were found.

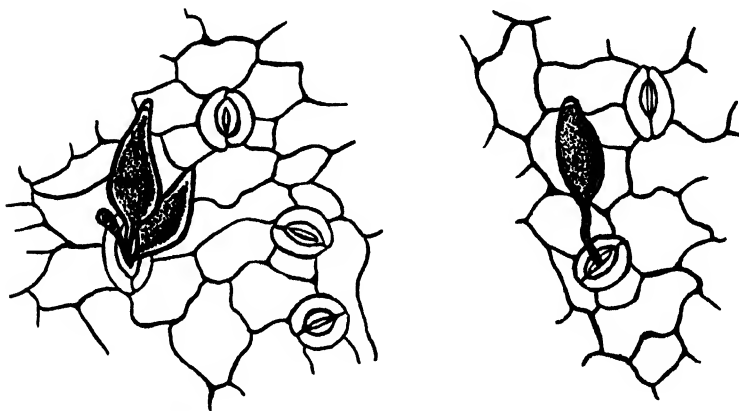


FIG. 5. Sporangia of *Phytophthora syringae* emerging from the stomata.

GEOGRAPHIC DISTRIBUTION OF THE FUNGUS

Berkeley (2) in 1881 describes, in the name of A. S. Wilson, the occurrence of large brown patches on lilac leaves, naming the fungus causing these spots, *Ovularia syringae*. He figures sporangia emerging from the stomata. Smith (11) in 1883 describes the oospores of the same fungus and A. S. Wilson (14) in 1886 the development and escape of the zoospores. G. W. Wilson (15) suggested already that *Ovularia syringae* Berk. is a synonym of *Phytophthora syringae* Kleb. Comparing the description of Berkeley of the patches on the lilac leaves and his figures with the forms found in nature, it is evident that Berkeley described the form of the disease occurring on the leaves and that *Ovularia syringae* Berk. is the same as *Phytophthora syringae* Kleb.

As already mentioned, Klebahn (4, 5) described the other form of the disease in 1905 and 1909, discovered near Hamburg, while the presence of the fungus in Holland was first made known by Schoevers (10) in 1913. In 1918 Arnaud (1) found *Phytophthora syringae* on lilacs in the garden of the Station de Pathologie végétale in Paris. Lafferty and Pethybridge

(7) in 1922 state that the rot of a couple of apples in Ireland was due to *Phytophthora syringae*.² They also mention having received formerly diseased lilac leaves suspected to be infested by the same fungus, but this could not be proved.

It is thus established that *Phytophthora syringae* occurs in Great Britain and Ireland, Germany, Holland, and France. It is highly probable that the fungus will also be present in other countries, the casual occurrence of leaf spots being easily overlooked.

In Holland it was proved by the presence of affected leaves that the fungus is not restricted to the lilac-growing centers for it was also detected in a garden where some isolated groups of lilacs were found.

INOCULATION EXPERIMENTS

Inoculation experiments were made to investigate the exact time of the year the fungus can live in the cortex, in which months buds will be susceptible, and if affected leaves have something to do with the attack on the stem. Therefore experiments were made by inoculating either stem, buds or leaves. With only a very few exceptions all inoculations were made on the white variety, Marie Legraye, as the brown coloring of the buds is here much more easily detected than with the blue varieties with their dark violet bud scales.

Stem Inoculations

A wound was made with a sterile scalpel in the bark, a pure culture of fungus was inserted in the wound, which was then closed and covered. Controls were treated in the same manner, using only sterile media instead of a pure culture. They all remained healthy and will therefore not be mentioned any more.

The disease developed normally when the inoculation was made in winter, but in summer it had no result. In most cases the tissue in the immediate neighborhood of the inoculation, however, was killed and turned brown, and the presence of *Phytophthora* mycelium was often suspected, but only a very short piece of tissue was attacked, the rest remaining healthy. This killing of the tissue may be due to some toxic substance in the medium secreted by the fungus or the fungus may be able to start some growth in the wounded cortex, which, however, soon ceases as the normal growing tissues are reached. Therefore an inoculation was only counted as successful if the cortex was brown for a distance exceeding 3 cm.

² It may be worth while mentioning here, that the writer with inoculations of *Phytophthora syringae*, isolated from diseased lilac branches, on apples, pears, and sour cherries still hanging on the trees got a certain percentage of rotted fruit from which the fungus could be reisolated.

In table 1 are shown the results of inoculations experiments made in the different months. It is to be seen that during the resting period the cortex is most susceptible. As soon as new growth of the lilac starts in spring, the fungus does not seem able any more to live from the tissues of the host plant. In 1923 the cambium started its function in the beginning of April. In the end of March no new tissue was observed, while on April 14th a single row of large new vessels was already formed.

The development of the fungus not only ceases as soon as the growth of the host plant starts, but the fungus seems even to die. In the diseased cortex and even in the small parts of killed tissue of the inoculations made in summer, oospores were found in quantity suggesting they might endure the unfavorable circumstances of summer; still never has any plant spread the disease in the following winter even when all the diseased branches were left on the stem, nor was it possible to reisolate the fungus in summer either from old diseased branches or from the small brown parts in the neighborhood of fresh inoculations. In winter, reisolations from diseased branches are very easily made. The few successful inoculations of July and August may be due to the fungus keeping alive till more favorable periods, perhaps in the form of oospores. The disease did not show on these branches till mid-winter. When the cambium stops growing is not known. Still its function will never be so strong in autumn as in the beginning of

TABLE 1.—*Results of stem inoculation with Phytophthora syringae*

Month and year in which inoculations were made	Number of inoculations	Number of successful inoculations. Cortex being brown for more than 3 cm.	Per cent successful
Jan., 1923	6	6	100
Feb., 1921-23	10	5	50
March, 1921-23	20	11	55
April, 1921	10	1	10
May, 1920-21	22	0	0
June, 1921-22	20	1 ^a	5
July, 1920-21-22	39	2	5
Aug., 1921-22	17	2	12
Sept., 1920-21-22	21	14	66
Oct., 1921-22	22	22	100
Nov., 1920-21-22	24	24	100
Dec., 1922	12	12	100

^a This tree was kept wet daily during 7 weeks. Of 5 inoculations only this one was successful, but the tree was in such an abnormal state, that the further course of the disease could not be followed.

spring. Therefore the fungus may perhaps keep alive during this time without yet being able to develop very much. This concerns also the inoculations made in September and October, as strong development of the fungus in the cortex only starts in December, as is demonstrated in table 2.

Table 2 shows the increase in length of diseased cortex in the different months gathered from the results of bud inoculations as well as of stem inoculations. In general the rate of growth is rather slow. Development of some importance starts only in December; in January and February maximum of growth is reached, decreasing slowly till it stops in May. In spring the part of the stem between the developing buds and a higher situated diseased piece will not be in normal condition, not getting the normal flow of sap. Therefore the fungus will in that part still be able to develop. Thus it is quite comprehensible that some growth of an already diseased branch is still possible in April while new inoculations do not succeed any more, which is demonstrated by comparing tables 1 and 2. It was often observed in spring that the disease ceased to advance as soon as the fungus reached a node with developing buds. The abnormal conditions produced by being cut off from the normal flow of sap may also be the reason for the difference in growth in both directions, the development of the disease in the top part decreasing less in spring.

The conclusion to be drawn from both tables is that *Phytophthora syringae* can invade the living tissues of the cortex of the lilac stem from December till April.

TABLE 2.—Increase in length of diseased cortex

Month and year in which observations were made	Increase in length of diseased cortex in direction of top		Increase in length of diseased cortex in direction of stem	
	Number of observations	Average increase in length	Number of observations	Average increase in length
Oct., 1920	3	0.0 cm.	6	0.1 cm.
Nov., 1920-22	15	0.1 cm.	18	0.2 cm.
Dec., 1920-22	21	1.9 cm.	21	1.2 cm.
Jan., 1921-23	11	1.9 cm.	38	3.0 cm.
Feb., 1921-23	8	3.0 cm.	82	3.1 cm.
March, 1921-22-23	11	2.9 cm.	131	2.3 cm.
April, 1921-22-23	18	1.9 cm.	208	1.0 cm.
May, 1920-21-23	10	1.0 cm.	27	0.7 cm.
June, 1920	7	0.5 cm.	7	0.1 cm.
July, 1922	5	0.0 cm.	5	0.0 cm.

Bud Inoculations

A series of bud inoculations was started in 1922, as preliminary experiments showed that, even as the cortex, the buds are not always susceptible to infection. Each fortnight a number of inoculations was made with the same strains of the fungus cultivated as much alike as possible. A piece of pure culture was brought between the bud scales. The 4 upper buds of 10 to 12 branches were inoculated at the same time. Thus the number of inoculations could be rather large, the drawback, however, was that the buds of one branch influenced each other to some extent. As, however, all branches were in the same condition, the results are quite comparable, only the percentage, especially of the very first ones, is perhaps a little too high. At the same time three branches were used as controls, a piece of sterile medium being brought between the bud scales. All controls remained healthy.

On many buds, brown spots were formed soon after the inoculation was made. These spots, however, did not always increase in size and the buds developed quite normally in spring. This spotting must be due to the substances formed by the fungus and present in the piece of medium used. To prove this, some cultures were heated for half an hour at 52° C. by which proceeding the fungus was killed. If a piece of this medium was used for inoculation, the majority of the buds showed the same brown spots and developed also quite normally in spring.

If the inoculation was, however, successful, the brown spots increased in size, till the whole bud was killed and after some time the cortex under the bud was attacked as well (Figs. 2, 3). None of the buds were quite brown before December. Inoculations made in September, October, and November were in December at the same stage; those of November even being distinctly in advance of those made earlier. Inoculations made after November showed the first brown bud after about five weeks. Therefore, it is highly probable that real susceptibility of the buds dates from the end of October, the successful inoculations of September and beginning of October being due to the fungus keeping alive between the bud scales.

Table 3 gives the results of the bud inoculations, those of the preliminary experiments in 1921 are added as well. Figure 6 shows a graph of both. After the maximum of November and December the susceptibility decreases gradually till it reaches a minimum in January, increasing again afterwards. This is followed by a new decrease till all susceptibility ceases with the development of the lilac buds. Both lines of the two years correspond rather well. The diminishing of susceptibility in January is not due to weather conditions, as may be thought, as in 1922-23 the temperature was rather regular during the whole winter, the first cold period occurring

TABLE 3.—*Bud inoculations with Phytophthora syringae*

Date on which inoculations were made	1922-1923			1920-1921		
	Number of buds inoculated	Diseased buds	Per cent diseased	Number of buds inoculated	Diseased buds	Per cent diseased
8 Sept.	40	0	0			
22 Sept.	40	20	50			
6 Oct.	52	30	57			
20 Oct.	48	44	91			
3 Nov.	48	48	100			
17 Nov.	48	41	85			
1 Dec.	48	48	100			
15 Dec.	48	36	75			
29 Dec.	48	34	71			
30 Dec.				16	14	87
12 Jan.	48	15	31			
14 Jan.				43	28	65
26 Jan.	48	33	69			
4 Feb.				20	17	85
9 Feb.	48	29	60			
18 Feb.				20	10	50
23 Feb.	48	24	50			
8 March				18	3	16
9 March	48	4	8			
18 March				22	2	9

only in February. If a graph is made of the number of diseased buds 8 weeks after inoculation or of the augmentation of diseased buds recorded each week, the same kind of curve is the result. This indicates that it is the real internal condition of the buds which influences the development of the fungus and not external circumstances.

The conclusion to be drawn from the bud inoculations is that lilac buds are more or less susceptible to infection of *Phytophthora syringae* from about the end of October till the end of February. This period corresponds with the time found by Versluys (12) for the rest period of the buds of Marie Legraye.

The decrease of susceptibility in January may be attributed to some other cause. Larkum (9) states that lilac buds contain their maximum of starch in November, the quantity decreases till a minimum is reached in the midst of January. In the beginning of February the quantity of starch augments again till a new maximum is reached with the beginning of the development of the buds. This change in food corresponds with the greater or lesser susceptibility of the buds during winter months. The entire

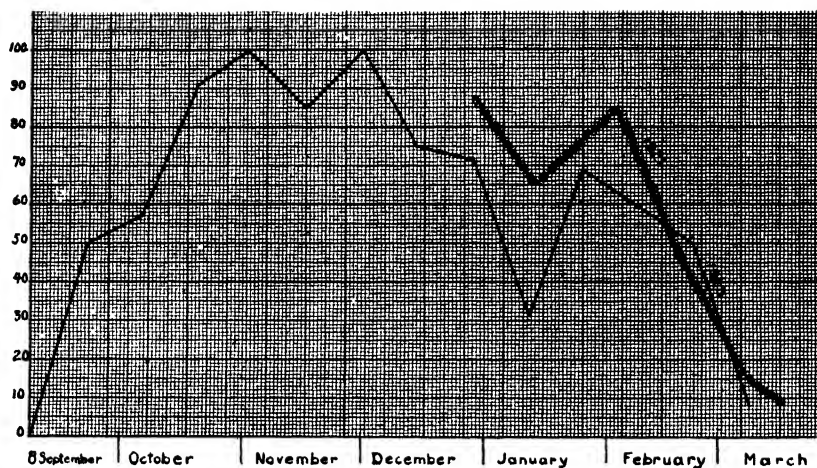


FIG. 6. Results with bud inoculations at different seasons of the year.

ceasing of the development of the disease, as soon as growth of the host tissue starts, cannot, however, be attributed to this change of food as a new maximum of starch is recorded in March. This non-growing of the fungus in developing tissues is thus found in the buds as well as in the cortex, the earlier growth of the buds causing the spreading of the disease in the buds to cease at an earlier date.

According to the theories of some authors, Lakon (8), Klebs (6), the accumulation of assimilation products by inactivating enzymes is the cause of the rest period of plants, while growth is due to the enzymes regaining gradually their activity. Weber (13) thinks that the increased activity of enzymes in developing tissues is not the cause of growth but a secondary factor. However this may be, increased activity of enzymes in growing parts is also accepted by him. This increase may explain the fact that *Phytophthora syringae* cannot live in the growing tissues of the host plant. It must be supposed, then, that the enzymes present in the growing parts are reversed to the development of the fungus and that their partial or entire inactivity during the rest period only enables the parasite to develop.

Leaf Inoculations

For the inoculations of the leaf not only the variety Marie Legraye was used, but also different seedlings. The best method proved to be to put a piece of pure culture on the leaf, covering it with some moist cotton wool and keeping this together by rolling and binding the whole leaf. In this manner some 90 inoculations were made in August, September, and October

of different years, resulting in 89 diseased leaves. Controls were treated alike, a piece of sterile medium being used instead of the pure culture. They all kept healthy. Most of the affected leaves fell prematurely. This premature dropping of the affected organ is a feature mentioned in many *Phytophthora* diseases. Of the 89 diseased leaves only 4 were still hanging on the stem a month after inoculation and only 1 remained on the tree longer than normal.

To investigate if this premature dropping of the leaves will prevent the entrance of the fungus through the petiole into the stem, cultures were made of 34 petioles as soon as possible after the leaves dropped. From 4 petioles *Phytophthora syringae* was isolated but only from some parts of the petiole, never from all. Still this indicates that with strong development of the fungus under favorable conditions the fungus may be able to enter from the petiole into the stem. The following observation strengthens this opinion. The inoculated leaves were a source of new infections on the neighboring ones, the lower leaves especially being infected by the falling drops loaded with fungus spores which developed abundantly under the moist cotton wool. The result was that after some time not only the inoculated leaves but the majority of them, belonging to the trees used, were affected. It was on 5 branches of these plants that for the first time natural infection of the cortex and buds was observed in winter in the experimental plot. This indicates even where the special inoculations of leaves had no direct results, to look to the affected leaves as the natural infection source of the branches in nature.

A search was made in the autumn of 1923 for diseased leaves with brown petioles. Only a very few were discovered, in Aalsmeer as well as on the experimental plot, which remained on the stem for an abnormally long period. Their leaf traces differed from the normal ones through a dark violet color, while all the surrounding tissues were quite healthy (Fig. 4). In this dark part mycelium was found. Isolations of the fungus were tried; they had no result in November, but in December from 7 of 8 colored leaf traces *Phytophthora syringae* was isolated, while in 10 normal green ones from the same branches no fungus was found. Two branches of this last plant grown under similar conditions were left on the stem and they were the only ones to show natural stem infection in 1924. It is thus proved that under special circumstances diseased leaves can be the cause of the attack on the stem.

Anatomy

Mycelium of *Phytophthora syringae* was present in the cortex between the green cells at a distance of 4 mm. from the brown part. The brown color

is thus not due to an action of the fungus in advance. The disease spreads along the cambium, then the inner layer of the cortex between the scleroid cells and cambium is attacked and then the outer layer. The distance, however, from the place where only the cambium is affected to that where the whole cortex is brown, is on the average less than 1 cm.

The presence of the mycelium is not restricted to the cortex but it was also discovered in the wood-vessels. In the wood it is mostly found near the cambium, sometimes extending further, once it was even present in the pith. The wood acquires a dark violet color, as has already been described for the leaf trace. To prove that it is really *Phytophthora syringae* and no secondary fungi which are present, cultures were made of the wood after removing very carefully all parts of the cortex and *Phytophthora* was isolated.

DISCUSSION

Klebahn (5) has already shown that stem inoculations are only possible after wounding and as the fungus can only live in the cortex during winter, it is not very probable that in nature stem infection takes place. An isolated case may be the result of wound infection, but it can never be the cause of an epidemic.

It is more likely that buds are the place of entrance of the fungus, still this disagrees with the facts known. In Aalsmeer in October, 1922, many affected leaves were found, proving that the fungus was generally present. November and December were very moist and the experiments showed that during these two months the buds are most susceptible, still not a single diseased branch was observed during the whole winter. If the buds are the place of infection, it is likely that the disease would be found more regularly, as buds are susceptible during the whole winter and on the average some moist period occurs during that time.

As neither the stem nor the buds seem to be the place of infection, the affected leaves may still be the cause of the attack on the branch. As has been shown previously the mycelium may enter from the petiole into the stem in certain cases. At the moment of leaf dropping the fungus is not yet able to live in the cortex, but it stays in the leaf trace, its presence there being easily detected by the violet color of the tissues. The fungus keeps alive in the leaf trace till the condition of the cortex enables it to live from the cortex cells, which happens in December. From here it spreads attacking the buds from inside. If this really is the natural mode of infection, the buds will not be killed until January. This corresponds with the known facts. In 1913 in Aalsmeer the diseased buds were not noticed till after January 1 and it was observed that the inner bud scales were often the first to acquire a brown color. If a plant harboring the fungus in its

leaf traces is used for forcing before January not a trace whatever of the disease will be found, as the experiments showed that the development of the fungus stops as soon as the tissues of the host plant starts growing.

Also the occurrence of epidemics is easily explained by the leaves being the place of entrance of the fungus. The affected leaves have a tendency to drop prematurely, thus in normal cases no attack on the stem will take place, which corresponds with the entire absence of the disease in most years. It will only be under abnormal circumstances that the fungus will be able to enter into the stem from the petiole before the leaves drop. Investigations of the weather charts to see what conditions can have been the cause of special circumstances in 1912 and 1918, showed that in both years an abnormal rainfall was recorded in August and September. In 1912 precipitation occurred on 37 days between August 1 and September 10, while in 1918, of the 30 days of September 29 were rainy. This amount of moisture will probably enable the fungus to develop on the leaves to such an extent that the mycelium can enter the stem before leaf dropping. Besides it will also be favorable for the dissemination of the fungus as sporangia will be formed in great quantity on the diseased leaves.

It has been shown previously (3) that *Phytophthora syringae* can easily grow in the soil as a saprophyte. This accounts for the fungus being generally present throughout the year. If abnormal rainfall occurs in some period other than August or September, it will also cause strong development of the fungus in the soil and consequently on the leaves, but it will never result in attack on the stem for the fungus will not keep alive in the cortex as the inoculation experiments have proved.

Thus it is only under very special conditions, *viz.*, abnormal rainfall in August or September, that *Phytophthora syringae* is becoming of economic importance. In general the fungus will be quite harmless, causing only the spotting and dropping of some leaves and if circumstances are not favorable it will not become parasitic, but live only in saprophytic form. Thus it may be counted as one of the hemi-saprophytes. Its parasitism is neither very specialized as is demonstrated by the fact that lilacs and apples both are attacked. Also Klebahn was able to infect other plants than lilacs. This scanty specialization of parasitism is a characteristic of many other species of *Phytophthora*, the majority of them attacking several host plants, belonging to quite different families. In this genus therefore care should be taken in using inoculation experiments to identify species.

CONTROL OF THE DISEASE

Measures for controlling the disease are only wanted in years when very abnormal rainfall occurs in August or September. The presence of a large number of affected leaves will indicate the danger of a future epidemic.

Even in those years control is only wanted for those plants which are to be forced after January.

The only way to prevent the attack on the stem will be by removing the leaves before the fungus has entered the leaf trace through the petiole. The general method, used by the cultivators to produce leaf dropping, which is necessary for early forcing, by putting the plants in dark under cover, just favors the development of the disease. So the only way to remove the leaves will be through picking by hand.

Bordeaux mixture also causes the leaves to drop but it may injure the buds to some extent at the same time, thus diminishing the value of the flowers. Experiments are still in progress with lime-sulphur, but no definite results are yet obtained.

SUMMARY

Phytophthora syringae not only attacks the buds and stem of lilacs but it also affects the leaves.

Conditions present in growing tissues prevent the development of the fungus, thus it can only live in the cortex of the lilac from December till April, while buds are only susceptible from October till February. In nature, bud infection does not seem to take place.

In general, affected leaves drop prematurely, under special circumstances; however, the fungus is able to enter through the petiole into the stem. The natural attack on the stem and buds probably occurs in this way. The special conditions needed are abnormally plentiful rainfall in August or September.

Control measures are only wanted in those years and only for lilacs to be forced after December. Picking of the leaves by hand is recommended.

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LITERATURE CITED

1. ARNAUD, G. Le mildiou (*Phytophthora syringae* Kleb.) et malaides diverses du lilas. Annales des epiphyties. 6: 214-216. 1919.
2. BERKELEY, M. J. Lilac fungus. Gard. Chron. 16: 665. 1881.
3. DE BRUYN, H. L. G. The saprophytic life of *Phytophthora* in the soil. Meded. Landbouwhoogesch. Wageningen, 24^a: 37 p., 2 pl. 1922. Literature, p. 35-37.
4. KLEBAHN, HEINRICH. Eine neue Pilzkrankheit der Syringen. Centralbl. Bakt. Abt. II, 15: 335-336. 1905.
5. ———. Krankheiten des Flieders. 75 p. Illus. Berlin. 1909.
6. KLEBS, GEORG. Über das Verhältnis von Wachstum und Ruhe bei den Pflanzen. Landbouwhoogesch. Wageningen, 24^a: 37 p., 2 pl. 1922. Literature, p. 35-37.
7. LAFFERTY, H. A., and G. H. PETHYBRIDGE. On a *Phytophthora* parasitic on apples which has both amphigynous and paragynous antheridia; and on allied species

which show the same phenomenon. Sci. Proc. Roy. Dublin Soc. 17: 29-43. Pl. 1-2. 1922.

8. LAKON, GEORG. Ueber den rhythmischen Wechsel von Wachstum und Ruhe bei den Pflanzen. Biol. Centralbl. 35: 401-471. 1915. Literature, p. 469-471.
9. LARKUM, A. Beiträge zur Kenntnis der Jahresperiode unserer Holzgewächse. (Dissertation) Göttingen. 102 p., 6 fig. 1914.
10. SCHOEVEERS, T. A. C. Ecne voor Nederland nieuwe seringenziekte, veroorzaakt door *Phytophthora syringae* Klebahn. Tijdschr. over Plantenziekten. Jaargang 19: 41. 1913.
11. SMITH, W. G. Resting-spores of the lilac fungus. Gard. Chron. 20: 439. 1883.
12. VERSTUYS, M. C. De periodiciteit van de knopontwikkeling bij Syringa. Meded. van de Landbouwhoogesch. Wageningen 22: 30. 1921.
13. WEBER, FRIEDL. Studien über die Ruheperiode der Holzgewächse. Sitzungsab. K. Akad. Wiss. Wien Math. Naturw. Kl. Abt. I, 127: 57-91. Illus. 1918.
14. WILSON, A. S. Birth of an ovularian zoospore. Gard. Chron. 26: 815. 1886.
15. WILSON, G. W. Studies in North American Peronosporales—V. A review of the genus *Phytophthora*. Mycologia 6: 54-83. 1914.

STANDARDIZING OF DEGENERATION DISEASES OF POTATO

H. M. QUANJER

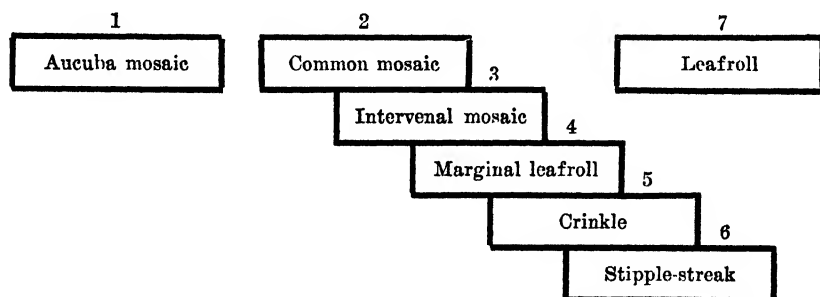
One of the first needs in the study of the potato-diseases, which in former years were thrown together as "curl" or were regarded as symptoms of degeneration, is the means of identifying each of them. Descriptions have been published for this purpose, illustrated by drawings (3) and water-colors (2), which give a clearer idea of their character than photographs. A collection of standard types is planted every year on the grounds of the writer's laboratory at Wageningen. The method of raising these "pure cultures" is the same as has been demonstrated during the International Conference for Phytopathology and Economic Entomology, Holland, 1923, by Dr. Oortwijn Botjes on the potato-selection farm at Oostwold-Oldambt for the raising of healthy strains of numerous potato-varieties. The Board of Agriculture has chosen this farm for this purpose, since no potatoes are grown in its vicinity and since the climate at Oostwold, on account of its situation near the North Sea, is not favorable for the spreading of the "degeneration diseases." The method is based on three principles: Selection, lifting in immature condition, and isolation. This selection farm is an example for improvement of potato culture in the whole country and at the same time supplies the disease-free plants for the laboratory at Wageningen (1).

The pure cultures of degeneration diseases are grown on the grounds near the writer's laboratory, situated amidst meadows at great distance from other potato-fields and exposed to the west-winds, a situation which is less favorable to the spread of these diseases than a sheltered garden would be. Seven diseases of this group have been demonstrated in pure form, during the Conference; there are more than seven, but in not all of them has the isolation in pure culture succeeded thus far.

A great difficulty in this work is that of establishing whether a certain pathologic condition of some potato variety, with which one is not familiar, is new or due to the one or other of these diseases.

It is a well-known fact that the symptoms of these maladies vary somewhat on the different varieties. Some of them are more heavily attacked and seem to degenerate more rapidly than others. In some the yield decreases markedly to remain then at a minimum for a number of years; in others failure to form any tubers and dying out of the line takes place in a couple of years; in still others the decrease in yield is so small, that it is difficult to say whether it is due to the disease or to environmental conditions.

It would be wrong, however, to suppose that these differences are so great and so marked that what may be, for instance, mosaic in one variety is stipple-streak in another or that the various maladies of this group are one and the same disease on various varieties or even one and the same disease under different environmental conditions. When potato plants of the same varieties are infected with the various known virus diseases and kept under the same environmental conditions they will produce complexes of symptoms that are decidedly distinct for each of the diseases and this distinction is constant, so long as the environmental conditions (temperature, moisture, and light) remain constant. The varietal difference of symptoms under consideration here is of another nature. All varieties infected with crinkle, for instance, show more or less typical crinkle symptoms, there are varieties that might display these symptoms in a much more pronounced form so that some of them may begin to resemble some of the symptoms of stipple-streak. On the other hand, there are varieties which, when infected with crinkle, may show the symptoms of the disease in such a slight form that some of them begin to resemble some of the symptoms of mosaic. It is therefore an overlapping of symptoms and not a changing of symptoms. This overlapping of symptoms is shown graphically below as it actually takes place.



Overlapping takes place only between Nos. 2-6. The intervarietal infections are useful not only in studying the relative severity of the various diseases on the various varieties but also for identifying pathologic conditions of unknown varieties. The diagnosing of a given potato virus disease with certainty is possible in most cases, only when we transfer it to one or more potato varieties whose behavior towards all of these diseases is well known. For this reason the "pure cultures" are kept growing in Wageningen in some of the Dutch standard varieties.

LITERATURE CITED

1. BOTJES, J. O. The potato-selection-farm at Oostwold. Rept. Intern. Conference Phytopath. and Econ. Entom. Holland, 1923: 142-147.
2. QUANJER, H. M. General remarks on potato diseases of the curl type. Rept. Intern. Conf. Phytopath. and Econ. Entom. Holland, 1923: 23-28. *Col. pl.* 1-4. Literature cited, p. 27-28.
3. ———. New work on leafroll and allied diseases in Holland. Rept. Intern. Potato Conf. 1921: 117-145. Illus. 1921. Literature, p. 144-145.

METHODS OF STUDYING THE DEGENERATION DISEASES OF POTATO

D. A T A N A S O F F

INTRODUCTION

The work on the well-known problem of degeneration in the potato, *Solanum tuberosum* L. has made valuable contributions during the last ten years towards the better understanding and solution of this problem. Unfortunately the complexity of the problem increases more and more with every new contribution towards its better understanding.

The problem was comparatively easy when there was known but one degeneration disease of this plant or rather when all degeneration diseases were known as one disease under the name of curl (2). It became two times or actually three times as complicated when the original disease was segregated into mosaic and leaf roll, and by the time the original disease was segregated into seven or eight different degeneration diseases the difficulties of the plant pathologist became still greater. The probable interrelation of some or all of these diseases to similar diseases of other plants and the actual existence of masked carriers of these diseases made the difficulties still greater.

All of the above named difficulties lay in the nature of things and while, in most cases, nothing can be done to lessen them, everything should be done to avoid increasing them. This is what the great majority of workers on these diseases have apparently neglected to do: First of all they have failed to give us in most cases exact and full descriptions of the symptoms and development of the various diseases during their various stages as seen in a certain variety and under given environmental conditions. Most descriptions of such diseases are so short and incomplete that no one can ever recognize the disease by using the existing descriptions, while the great majority of the illustrations of such diseases are of no diagnostic value whatever.

Most of the existing descriptions of such diseases are full of terms and expressions that have no distinct value for the reader. Unquestionably the authors of such terms associate certain diagnostic values with words like "dwarfing," "wrinkling," "streaking," "browning," "curly dwarf," "rusty dwarf," "yellow dwarf," "mosaic dwarf," "rugosity," etc., but for the reader such words are meaningless because they are too broad and too general and because they are not sufficient in themselves to describe a whole complex of symptoms. What is still worse is that one author calls a certain disease "leaf roll," another author speaks of the same disease as

"leaf curl;" one uses the name "streak," the other the name "stipple-streak" for the same disease; one speaks of "crinkle," the other of "rugose mosaic" and they both mean the same disease; one calls a certain disease "common mosaic," a second calls it merely "mosaic," while a third uses the name "mild mosaic" or "medium plus mosaic" for the same disease; one speaks of primary and secondary form, the other of current season or first and second season symptoms.

The only result of this deplorable practice is that even the men working on this problem cannot understand each other's writings, let alone those who are not familiar with these diseases.

It is really time for the various workers on this problem to come together to put an end to this chaotic and deplorable condition (15, p. 127, 128).

The aim of this paper, while offering no fundamentally new facts and opening no principally new perspectives, will be to outline some methods and offer some suggestions which may help to simplify and speed up the work on the virus diseases of the potato plant.

PRELIMINARY FIELD STUDIES AND COLLECTING OF MATERIAL

The first thing in the studying of any or all of the degeneration diseases of the potato plant is to learn what a healthy, normal, and vigorous potato plant of given variety looks like. It is useless trying to study the degeneration diseases of this plant (17) without knowing what a disease-free plant should look like.

The symptoms of most of the potato degeneration diseases vary considerably in the different varieties but they are constant on the same variety and under given climatic conditions. As a rule the varietal difference of symptoms consists on the one hand in a more pronounced, on the other hand in a less pronounced expression of the complex of symptoms accompanying each disease. So that the same disease might bring about in the different varieties shades and degrees of a given complex of symptoms. And it is indeed possible that certain of the symptoms, but not all symptoms of a disease, might be entirely absent on some varieties and very pronounced in others. For instance, tubers of stipple-streak plants may show pronounced peridermal discolorations (1, p. 8) in some of the highly susceptible varieties and no discolorations of the tubers whatever in other varieties. As a rule it can be said that the rapidly growing varieties with luxuriant, tender, and light colored foliage show more pronounced symptoms than the hardy, slow growing, and late varieties do. It is therefore advisable for everyone to limit his work, at first at least, to one variety and preferably to a variety which has been already used successfully for such studies by former workers. As such varieties may be mentioned: Green Mountain, Paul Krüger (President), Bliss Triumph, Bravo, etc.

The variety known in Holland under the name "Schotsche Muis" and in England under that of Victory, which is an unusually early potato, rapidly growing, early sprouting and highly susceptible for all kinds of diseases, will prove, in the writer's judgment, to be an excellent variety for studying the degeneration diseases of potato.

In trying to get a general idea of the various types of degeneration diseases of the potato plant, it is absolutely necessary to limit one's studies and observations exclusively to fields that are practically free from any degenerated plants. The better and the more luxuriant the condition of the plants and of the field in general, the greater is the chance that a portion of the few diseased plants will be in the primary stage of the disease. The newly infected plants in a first class field that have just got any of these diseases are much more apparent and the recognition of the diseased plants and the diagnosing of the disease is much easier than in a field where most of the plants are infected or otherwise injured. The slighter the symptoms of the diseased plants are the more suited they are for further study, since in most cases their disease will prove to be pure, *i.e.*, only one disease being present in each infected plant. Such plants when standing far from any other diseased plants should be marked and watched for the further development of the disease and eventually for the collecting of material. Such plants have the size, general appearance, and vigor of the healthy plants and cannot be distinguished from a distance. They can be recognized only upon a close and careful examination. The symptoms of the degeneration diseases become apparent first in the young and rapidly growing tops of one of the shoots; from the tops they advance downwards in the shoot and then in the sister shoots of the same hill.

Material, unless otherwise desired, should be collected or the plants dug out not before the symptoms have become distinctly visible in all shoots of a hill, but as soon as possible afterwards. If we get material or dig the plants at an earlier date as indicated above we are apt to collect material and tubers which have not yet been reached by the virus, on the other hand if one should delay too long digging the plants or collecting living material, for instance for sap or for graft infections, the plants may be meanwhile infected by some of the other virus diseases. The harvested tubers should be washed carefully without injuring their periderm, dried, fumigated,¹ to make sure that they are free from any insects, properly labeled, and stored. The washing is necessary because it enables us to see the effects of the disease on the tubers if such should be present, as they actually become apparent on some varieties (1, p. 12).

¹ Exposing the tubers for several hours to the fumes of nicotine extract (250 c.c. for every 40 m³ of space) will kill most insects that may be present on the tubers.

It is in most cases not advisable to collect material from plants that are in an advanced stage of the disease, first because most of the degeneration diseases in their advanced stages exhibit symptoms which are common to most of them, and which are much less typical than the respective symptoms in their primary form, and secondly because such plants as have been exposed to contamination for many generations may carry more than one disease.

There are at present no reliable methods for distinguishing, separating, and getting in pure condition the two or more diseases that may be present in the same plant, so that it is perfectly useless to experiment with such plants or tubers, which represent an unknown quantity. Those desiring to study combinations of degeneration diseases should self-infect healthy plants simultaneously with two or more of such diseases, instead of trying to analyze existing combinations of diseases.

Fields to be used for the studying and selecting of virus diseases should never be sprayed, because this masks many of the disease-symptoms. Such fields should be as free from insect injuries as possible, especially from flea beetles (*Epitrix* sp.), Colorado beetles (*Leptinotarsa decemlineata* Say), aphids, etc.

INFECTION EXPERIMENTS

By far the greatest difficulties in this problem (outside of absence of visible pathogens), lies in the somewhat longer incubation period of these diseases, under ordinary conditions and in the infection work. All this makes it necessary first to protect the inoculated plants from possible external contamination by insects or possibly other agencies, which is very expensive, in some cases impossible and requires much work and time. In the second place, should the symptoms of the disease fail to appear during the first season the tubers of every inoculated plant must be planted the following year. This means an increase in work and expenses equal to from five to ten times those of the first season, since for every inoculated plant of the first year we shall have to attend to from five to ten plants during the second year. Should one begin with several hundred of plants in the first year, the following year their number will amount to several thousands and the further the work proceeds the greater this number will become, so that before long the work must naturally become less productive, the chance of error increases to far beyond the permissible, while the financing of the problem become an impossibility. On the other hand, the very length of the experiments make their eventual results very doubtful, and not seldom the results may be not only negative but directly opposite to what they should be. It often happens that the plants infected with mosaic will develop leafroll in the second generation while their checks may show (for instance) mosaic symptoms. Schulz and Folsom (19, p. 65)

write also that "sometimes observations on the first generation in an experiment including the controls, are more valuable than those on the second generation." When a certain experiment fails to give final results during the first season it is far better to repeat it the following year than to try to get results by growing further the progenies of the infected plant.

All of the above difficulties would disappear automatically if it should be possible to modify the present methods of experimenting on these diseases in such a way that in all cases the infection-experiments could be completed during the same growing-period. This is not only possible but it can be accomplished with great ease and requires negligible expenditure, while the chance of error is practically diminished to zero and the probability of success becomes much greater.

Before discussing the methods by which the above can be accomplished, it may not be out of place to state that the old method of two-seasons-infection-experiments has made possible the important discoveries concerning the nature of the degeneration diseases, which form the foundation of our present knowledge of said diseases. This method was originally worked out in Holland by Quanjer and Oortwijn Botjes, afterwards it has been used by Murphy and Wortley, by Schulz and Folsom, and the writer.

Sprout Infection

That some of the diseases under consideration can be transmitted to sprouted tubers with certainty and great ease in the shortest possible time and with 100 per cent of positive results has been experimentally established by Murphy (13, p. 178), Schulz and Folsom (19, p. 87 and 91), and by the writer (3). There is no reason why the rest of these diseases could not be transmitted in same way. When infecting potato plants by means of sap, grafting or aphids, we can never be absolutely sure that the plant we are to infect is not already infected with the same or another disease, since absence of symptoms is in no case a guarantee that the plant is disease-free and the control plants can never serve as such, because they as well as the inoculated plants might get infected at any moment during their comparatively long vegetative period, as has been already pointed out. This is especially evident from Schulz and Folsom's last work on this subject (19) where in some cases the infected plants remained healthy while the checks became infected.

In most cases it is not possible to cage the inoculated and control plants so as to make absolutely sure that no infection from outside has taken place. This however can easily be accomplished if one works with sprouted tubers as it is possible to handle a tuber in such a way that it will never come into contact with insects. Moreover portions of the same tuber may serve as controls by forcing them beforehand, thus making it possible to ascertain

in advance whether the tubers to be used for the infection-experiments are disease-free or not, which can never be done with equal certainty when plants are used.

Schulz and Folsom (19, p. 51), experimenting with flea beetles as probable mosaic carriers, had difficulties in keeping the experimental plants free from aphids; they write: "In spite of special precautions, potato aphids were introduced with the flea beetles into some cages." "The difficulty with aphids is chiefly one of supplying the proper control conditions for inoculations on a large number of plants in the field" (19, p. 48). The certain exclusion or caging of aphids is a difficulty experienced by many workers.

Still another disadvantage of plant infections is that when aphids are used as disease carriers they may produce on the plants distinct mottling, crinkling, and chlorosis even when non-virulent, thus making impossible the interpretations of the presence or absence of certain symptoms. Besides this it necessitates the spraying or fumigating of the plants in order to free them from the insects if this becomes necessary.

A. *By aphids*

The most rational method of infecting sprouted tubers is by means of aphids. This has been done with potato-stipple-streak (3), mosaic (19), and leafroll (13); it can be done as follows:

The first thing needed is to secure a quantity of disease free aphids. In a very limited number of cases the writer obtained what proved to be disease-free aphids in the following way:

A number of full-grown aphids taken from diseased or healthy plants were placed on the sprouts of a healthy tuber which was then placed in a glass jar. To prevent other insects from entering the jars it is necessary to tie up a cloth around the opening of the jars. The cloth should be so fine that even the smallest aphids should not be able to pass through it. Many workers use for such purposes ordinary cheesecloth, this is however far from being adequate. The writer has been using a much finer fabric having 20 meshes per one centimeter in both directions, the space between the meshes being 0.35 mm. and he has repeatedly observed that the smaller aphids did pass freely through such cloth and left the jars even when there were no other tubers or plants in the neighborhood to attract them. The space between the meshes should not be more than 0.2 mm.

If the temperature of the room is not less than 18° C. new aphids are born at a quite rapid rate and when transferred immediately after their birth by means of a fine hair brush to the sprouts of a second healthy tuber, they proved to be free from any virus disease. Within two weeks the young aphids reach their full development and begin to propagate at an

astonishing rate, so that a few jars with sprouted tubers are sufficient to supply any quantity of aphids. The jars with aphids should be placed in the light. New jars with fresh tubers should be set every second or third month. Whether this method will give disease-free aphids in all cases and under all conditions is far from certain. The recording of this fact is worth the while in connection with McClintock and Smith's work on spinach mosaic, who showed that in the case of this disease even the 3d and 4th generation aphids were infectious.

The aphids so obtained are then placed on the sprouts of infected tubers. So long as the minimum period needed for the aphids to become infectious after feeding on an infected plant or sprout is not known, the aphids should not be removed from the infected sprouts and used for infection experiments before they have spent ten days on the infected tubers or plants. After securing a reserve of virulent aphids a number of full-grown aphids (10-15) are transferred to the one half of one or more sprouted healthy tubers, which have been cut longitudinally in two pieces and placed in a glass jar, while the second half or halves, are placed in a second glass jar.

Both jars, with and without aphids, are then placed for several weeks (6-8) in a room at a temperature of 20° C. to incubate. The room should be moderately moist and light. In this way it is possible to bring a maximum of inoculation into a minimum of plant cells, while the tender and growing sprout offers ideal conditions for the multiplication of the virus. Should the jars have been kept in darkness, which is not desirable, they must be placed before planting in the sun light for several (10-15) days. This is necessary for the hardening and thickening of the sprouts, otherwise they are apt to fall off during the planting. In the case of stipple-streak and in some cases of crinkle the symptoms of the disease may become apparent on the tubers and the sprouts within 5-6 weeks. But an incubation period of two months is to be preferred in most cases. The incubation of the tubers, as indicated above, is necessary for intensifying the infection. Tubers thus treated are fumigated to free them from the aphids and together with their controls are then planted at a time and under conditions that are known to be favorable for the development of the respective disease.² Care should be taken not to break off the sprouts. Such tubers, if only the soil temperature and moisture are favorable, will send shoots above the ground within a very short time and usually much earlier than tubers

² Before we learn something more regarding the optimum temperatures of the various virus diseases it will be advisable to keep the pots with the infected tubers at 18-20° C. A medium moisture of the air and a proper moisture of the soil, that will facilitate the rapid development of the plants, are also essential. In the absence of sufficient sunlight the plants grow very abnormally, which in turn precludes the appearance of typical symptoms.

planted without sprouts. The check tubers will form normal plants, because even if they should have been infected after their planting in the field the time during which they have been exposed to infection has been too short for the development of any symptoms. The plants from the infected tubers on the other hand will show in most cases pronounced symptoms of the secondary form of the disease, if only the temperature has not been too low. Herewith the particular experiment is definitely finished, within a minimum length of time, with no special expenses and work for caging of the plants and with a minimal chance of error or complications.

Should it be desired to obtain plants also with the primary form of the disease in the case of stipple-streak or gradations between primary and secondary symptoms of the respective disease one needs only to lessen more or less the period of incubation or to plant the incubated tubers in cooler soil.

An even better method of accomplishing this is by grafting a portion of a diseased tuber to the freshly cut half of a healthy tuber, tie them firmly together, let them stay for two days at room temperature, then plant them in pots. At first the shoots coming from the diseased half will be also diseased, those of the healthy tuber will remain healthy for some time and then show suddenly in their tops symptoms of primary infection.

B. Sprout grafting

Sprout grafting is not only much easier but it possesses all the advantages of the sprout infections and lacks all of the disadvantages of the infection of plants.

Sprout grafting is possible even in cases where plant grafting is impossible as in the case of stipple-streak: Most potato varieties when infected with stipple-streak wilt and die so soon that a grafted scion dies before the infection has passed into the grafted plant (1, p. 20). For sprout-graft infections it is necessary to place the infected tubers to sprout at a temperature of about 20° C. If lower or higher temperature are used the probability is not excluded that under certain conditions there may be formed sprouts that are free from the disease during a given period of time and may remain so if prematurely detached from the mother tuber. Whether this actually can take place is not positively known, but some field observations have suggested to the writer this possibility. The tubers of which sprouts have been grafted are placed for several days (10–15) in a moist chamber to facilitate the growing together of the graft and scions, they are then incubated at 20° C. for 5–6 weeks as described under sprout infection. Care should be taken that no insects come in contact with the tubers. The tubers should be kept in the light if possible for reasons already mentioned.

C. Grafting of tubers

Tuber-grafting, first used by Quanjer (15), is as useful as sprout grafting, only that in this case much more infected material is needed. In the first case several infected tubers can supply us with a large number of sprouts during a period of several months, whereas in the second case one infected tuber can serve for not more than 2 or 3 tuber graftings. The grafted tubers well protected from insects are incubated as usual in light rooms at 20° C. for 6-8 weeks, then planted if environmental conditions in the field are favorable.

Plant Infection

The results of plant graft infections are as instructive and as evident as the sprout infections are striking and should be used whenever possible, both as a check to other infection methods and as the only reliable method of infection where other methods may not be possible or are difficult as in late summer when tubers are no more available.

By far the largest part of the infection work done with the degeneration diseases of potatoes has been done with plants. Hence the greater popularity of this method. Here need only be emphasized the following two facts: The plants to be used for aphid, graft, or sap infections must be young, vigorous, and rapidly growing. Plants that are stunted, weak, of advanced age, slowly growing, or injured should never be used for infection experiments as very often they fail to show any symptoms.

Of just as great importance are the environmental conditions under which the infected plants grow. The temperature should not be much below or above 20°, the soil not dry and the air humidity not too low. The infected plants should get as much sunlight as is possible, since only a normal development of the foliage will make possible the appearance and recognition of the symptoms. The infections should be made at such a period of the year that the plants can pass at least two full months in active and normal growing before the appearance of any symptoms of ripeness.

Sap infections give better results when made on the leaves, preferably by leaf mutilation as used by Schulz and Folsom (19).

A. Plant grafting

When done early in the season with young and rapidly growing plants and under favorable environmental conditions the plant graftings also give final results during the same growing period. Next to the sprout infection method the plant grafting makes possible the transmission of a maximum of inoculum into the grafted plant.

This method is especially adapted for interspecific transmission of virus diseases. The studying of interspecific relationships of the virus diseases

is of great scientific as well as of practical importance. Such studies will also throw light upon the problem of alternate hosts which might serve to perpetuate and spread these diseases. This method of infection, first described in 1916 (15), makes it possible to watch and follow up the advancement of the disease from the scion, first into the nearest standing growing point, then into the next standing branches of the same shoot and finally into the sister shoots.

The freshly grafted plants must be kept for several days (6-7) in moist chambers, well supplied with light, to facilitate the growing together of the scion and the graft.

B. *Aphids*

The successful graft infections should be repeated with insects, since the possibility is not excluded that by the graft-method it may be possible to transmit in some cases a particular disease to a plant to which it is never transmitted in nature and even to produce distinct pathologic changes, in some cases resembling those of the natural host. In this connection it must be emphasized that none of the above methods of infection alone will be sufficient to establish the identity or difference of given virus diseases of different plants. Further investigations and finer methods, peculiar for each case, will be needed for settling such questions.

Failure to produce any symptoms on the grafted plant is no proof that the virus present in the scion has not passed and spread throughout the same, since there are many known cases of the so-called "susceptible masking" hosts or symptomless carriers (15, p. 132). The possibility of the existence of intermediate hosts (7, 19, p. 88) should also be borne in mind. It may be possible to transmit a certain virus disease to a certain plant only by transmitting it first through an intermediate host.

For infections with aphids one should take several tuber-sprouts covered with aphids from the aphid stock-jar and place them on the tops of the caged healthy plant. If one transfers only the aphids one is apt to injure a larger percentage of the aphids. Less reliable for this purpose is the method used by Schulz and Folsom (19), which they call aphid dispersal, *i.e.*, one healthy plant is caged with a diseased plant on which aphids are present. In this case the rôle of soil and other insects, which may possibly circulate under this condition from plant to plant, is not excluded. So long as this subject has not been investigated thoroughly we have no right to suppose that the soil insects play a rôle in the transmission of such diseases. And indeed the writer has some circumstantial evidence that wire worms may play a part in the spreading of stipple-streak and possibly of other diseases.

INCREASING OF THE INFECTED MATERIAL

Not seldom the infected material (tubers) of a certain disease or of a particular variety actually suited for further experimenting may be so limited that no work on any scale can be undertaken with such material. Under the present conditions such material has to be planted the following season with the hope of obtaining more tubers which is not always done; besides it takes a great deal of time. This can be done with a much greater certainty and in much shorter time by grafting portions of the infected tubers to large and healthy tubers of the desired variety. The piece of the infected tuber is tied firmly against a freshly cut surface of a large and healthy tuber. The grafted tubers are kept at a temperature of 20° C. for 6-8 weeks to incubate them thoroughly. After the incubation the tubers are thoroughly infected and can be used further as infection material. In this way it is possible to increase the material several times, since every one of the small diseased tubers will give 2-3 large tubers after the grafting. If desired, the newly infected tubers can be used further for the multiplication of the diseased stock. The writer has used this method with the stipple-streak disease with great success.

TIME OF FIELD PLANTINGS

The potato can grow and develop a normal and very luxuriant growth at comparatively low temperature if only sufficient sunlight is present. Most of the virus diseases of this plant on the other hand require a much higher temperature for their development so that their development can not only be retarded but even completely suppressed by low temperatures which are high enough to permit a normal development of the plants. Under such conditions one may obtain apparently normal plants from positively infected tubers (1, p. 22), which continue to grow normally until after the coming of warmer weather. Meanwhile the plants reach their full development, and as such usually fail to show any symptoms of the disease even after the rising of the temperature. The young leaves, on the other hand, show, after the rising of the temperature, no longer the secondary symptoms of the disease in question, as they should have done had the temperature been favorable for the disease, but the primary symptoms of same; thus giving us an entirely different result from what it would have been had the plants been grown from the very beginning at a temperature favorable also for the development of the disease. It is nothing unusual for such plants to form a large number of fully developed tubers, whereas at temperatures favorable also for the development of the disease, they may not form any tubers at all.

Field plantings, therefore, should never be done at a time when the soil and air temperature are too low, that is, field plantings of infected material

should not be done too early in spring, and yet as early as possible, because a too late planting, as has been pointed in an earlier chapter, will increase the chance of outside contaminations and might thus decrease the value of the results.

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LITERATURE CITED

1. ATANASOFF, DIMITAR. Stipple-streak disease of potato. Meded. Landbouwhoooges. Wageningen 24, No. 5., 52 p., 5 pl. 1922. Literature cited, p. 29.
2. ————. A study into the literature on stipple-streak and related diseases of potato. Meded. Landbouwhoooges. Wageningen 26, No. 1., 52 p. 1922. Literature cited, p. 47-52.
3. ————. Stipple-streak disease of potato. Rept. Intern. Conf. Phytopath. and Econ. Entom. Holland 1923: 32. 1923.
4. BARRUS, M. F., and CHUPP, C. C. Yellow dwarf of potatoes. Phytopath. 12: 123-132. Pl. 7-8, 1 fig. 1922.
5. COTTON, A. D. The situation with regard to leaf curl and mosaic in Britain. Rept. Intern. Potato Conf. 1921: 153-168. 1922.
6. DOOLITTLE, S. P., and WALKER, M. N. Notes on cucurbit mosaic. (Abstract) Phytopath. 12: 42-43. 1922.
7. ————. Cross-inoculation studies with cucurbit mosaic. Science 57: 477. 1923.
8. ELMER, O. H. Mosaic cross-inoculation and insect transmission studies. Science 56: 370-372. 1922.
9. JOHNSON, JAMES. The relation of air temperature to the mosaic disease of potatoes and other plants. Phytopath. 12: 438-440. 1 fig. 1922.
10. MURPHY, P. A. Investigations of potato diseases. Bull. Exp. Farms Canada II, Div. Bot. 44. 86 p., 35 fig. 1921. Literature cited, p. 83-86.
11. MURPHY, P. A. Some recent work on leaf-roll and mosaic. Rept. Intern. Potato Conf. 1921: 145-152. 1 pl. 1922.
12. ————. Leaf-roll and mosaic, two important diseases of the potato. Jour. Dept. Agric. and Tech. Instr. Ireland 22: 281-284. 1 pl. 1922.
13. ————. On the cause of rolling in potato foliage; and on some further insect carriers of the leaf-roll disease. Sci. Proc. Roy. Dublin Soc. 17: 163-184. Pl. 6. 1923. Literature cited, p. 183.
14. ORTON, W. A. Streak disease of potato. Phytopath. 10: 97-100. Pl. 8. 1920.
15. QUANJER, H. M., H. A. A. VAN DER LEK and J. O. BOTJES. On the nature, mode of dissemination and control of phloem-necrosis (leaf-roll) and related diseases. Meded. van de Rijks Hoogere Land-Tuin-en Boschbouwsch. 10: 91-138. 12 pl. 1916.
16. QUANJER, H. M. The mosaic disease of the Solanaceae, its relation to the phloem-necrosis, and its effect upon potato culture. Phytopath. 10: 35-47. 14 fig. 1920. Literature cited, p. 47.
17. ————. New work on leaf-curl and allied diseases in Holland. Intern. Potato Conf. 1921: 117-145. 20 fig. 1922. Literature cited, p. 144-145.

18. ————. General remarks on potato diseases of the curl type. Rept. Intern. Conf. Phytopath. and Econ. Entom. Holland 1923: 23-28. *Pl. 1-4 (col.)*. 1923. Literature cited, p. 27-28.
19. SCHULTZ, E. S., and DONALD FOLSOM. Transmission, variation, and control of certain degeneration diseases of Irish potatoes. Jour. Agric. Research 25: 43-118. *15 pl.* 1923. Literature cited, p. 115-117.

PHYTOPATHOLOGICAL NOTES

Institutions for Phytopathology and Economic Entomology in Holland.—Until recently the Dutch Phytopathological Service was connected with the "Institut voor Phytopathologie" under the directorship of Prof. Ritzema Bos. The scientific work of the "Institut" was by this arrangement seriously hindered. After the retiring of Prof. Ritzema Bos, the service has got its own Director, Ir. N. van Poeteren, with headquarters at Wageningen, its task is inspection, advisory and extension-work. The task of the "Institut voor Phytopathologie," which is a department of the University of Agriculture, Wageningen, is teaching and research. It has now three laboratories: in the original building the laboratory for entomology is now being equipped under the direction of Prof. W. Roepke. A new building at Wageningen has been built for mycology and potato-research under the direction of Prof. H. M. Quanjer. The third laboratory, also newly built and equipped for flower-bulb research, situated at Lisse, amidst flower blub fields, is directed by Dr. van Slogteren.

In the second of these laboratories the teaching is chiefly done by Prof. Quanjer, assisted by Miss J. H. H. v. d. Meer; research is the main work of Miss H. L. G. de Bruyn, Dr. D. Atanasoff, and Ir. S. J. Wellensiek, and a number of graduate students. About 15 acres of ground belongs to this laboratory; besides the subsidized potato-selection farm of 120 acres, under the direction of Dr. Oortwijn Botjes, at Oostwold, Oldambt, the aim of which is to help the laboratory in growing healthy potato varieties for infection experiments (*c.p.*, this No. of Phytopathology: "Standardizing of degeneration diseases of potato").

The Phytopathological Laboratory, "Willie Commelin Scholten," the seat of the "Central Bureau voor Schimmelcultures," is an endowed institution for phytopathological research. It is directed by Prof. Johanna Westerdijk, who also teaches phytopathology at the department of botany of the University of Utrecht.—H. M. Quanjer.

Hösterman, Gustav, Noack, Martin. Lehrbuch der pilzparasitären Pflanzenkrankheiten mit besonderer Berücksichtigung der Krankheiten gärtnerischer Kulturgewächse, 271 pages, 104 text figures, 1903, Paul Parey, Berlin. Price M. 9. This volume is intended to fill the gap in the more general works of Frank, Sorauer and V. Tubeuf and is devoted more especially to the diseases of garden crops. The introductory matter on the classification of the important groups of fungi concerned in disease is well written and helps the student to obtain certain necessary fundamentals for the special sections which follow. The practical considerations in the treat-

ment of the important pathogenic groups are clearly presented. A special and helpful feature of the book is a key to the more important fungi which cause disease in garden crops. The key is arranged according to the host plant and will be most helpful to the beginner. The illustrations are selected with considerable care to present the subject in hand. The volume should prove useful to all students of plant disease.—JAMES R. WEIR.

Endothia parasitica. Dans une communication faite à la sernière réunion de Cincinnati de l' "American Phytopathological Society" et reproduite dans le numéro de janvier dernier de ce journal (vol. 14. No. 1, p. 52) M. Haven Metcalf a annoncé la découverte qu'il avait faite, en Belgique, à Bruges, du redoutable *Endothia parasitica* du Châtaignier.

M. Marchal, Directeur de la Station de Phytopathologie à Gembloux me fait savoir, à ce sujet, qu'il s'est livré, avec la collaboration de M. Van Hove, chef du Service d'Inspection phytopathologique, à une enquête, à Bruges et dans les environs.

Il résulte de leurs recherches que le cas observé par leur savant collègue américain devait être un cas tout-à-fait isolé car toute trace d'*Endothia* a actuellement disparu.

Ils concluent de leur enquête que l'on peut encore considérer, à l'heure actuelle, la Belgique et l'Europe comme indemnes de ce champignon.—H. M. Quanjer.

Third Pan-American Scientific Congress Postponed. Notice has been received that the Third Pan-American Scientific Congress which was scheduled to commence November 16, 1924, has now been postponed to December 20. The reason given for this postponement is that more scientists will be able to attend during the latter part of December than during November. The period during which papers or summaries thereof, which do not exceed 1,500 words, will be received has been extended to November 1.

Annual Meeting of the American Phytopathological Society.—The Society will hold its meetings at the Central High School, Washington, D. C., during the three day period December 30 to January 1. As usual this meeting is in conjunction with that of the American Association for the Advancement of Science. In addition to the customary joint session with Section G the Society will meet with the Mycological Section of the Botanical Society of America for the presentation of papers of common interest. At least one session will be devoted to papers on pathological subjects which are in the nature of finished pieces of research. The majority of the papers, however, will probably be presented to two or more groups of the Society

in simultaneous session. An attractive additional feature of the meetings this year will be the opportunity to visit the Department of Agriculture and other points of interest about Washington. The Phytopathologists' Dinner with its entertainment program will take place on Thursday evening, January 1.

The New Ebbitt Hotel at 14th and F Streets will be the headquarters for the Society and for the Botanical Society of America.

Laboratory facilities at Naples, Italy. Any biologists wishing to do laboratory work in Italy during 1925 should consider the facilities offered by the Stazione Zoologica at Naples. Because of a grant made to this station by the American Association for the Advancement of Science the association is entitled to name the occupants for a "table" at that station, where, according to the Director, Dr. Dohrn, arrangements have been made for work with plants as well as animals.

Any American or Canadian biological worker is eligible and if there are any interested they should communicate with the permanent secretary of the American Association, Dr. B. E. Livingston, Smithsonian Institution Building, Washington, D. C.

Personals. Dr. Caroline Rumbold, formerly in the office of Sugar Plant Investigations, Washington, D. C., is now in the office of Forest Pathology, Madison, Branch, Old Soils Building, Madison, Wisconsin.

Dr. F. L. Stevens will attend the Pan-American Scientific Congress in Peru as a delegate from the University of Illinois, from the American Association for Advancement of Science, and from the American Phytopathological Society.

Dr. L. W. Durrell, formerly assistant plant pathologist at the Iowa Agricultural Experiment Station, has been appointed head of the department of botany of the Colorado State Agricultural College.

PHYTOPATHOLOGY

VOLUME XIV

NUMBER 12

DECEMBER, 1924

PHYSIOLOGICAL SPECIALIZATION OF *USTILAGO HORDEI*

JAMES A. FARIS¹

WITH ONE FIGURE IN THE TEXT

In a previous paper (1) I have reported extensive experiments upon the factors influencing the infection of barley by the covered smut fungus (*Ustilago hordei*). In these experiments very high percentages of infection were obtained over a wide range of soil temperature and acidity and at moistures well within those usually existing when barley is planted in the field. Seed of Hannchen barley was germinated in soils of two moistures (40 and 50 per cent) and four pH reactions at six different temperatures from 5° to 30° C. The averages of the two moistures and four pH values gave 6.7 per cent infection at 5° C.; 60.6 per cent at 10°; 61.4 per cent at 15°; 53.9 per cent at 20°; 35.7 per cent at 25°; and 3.7 per cent at 30°. Still higher percentages were secured when the soil temperature was varied.

Considerable data were also given which could be explained only upon the basis that the covered smut fungus, *Ustilago hordei* (Pers.) K. & S., is made up of several biologic forms, a condition unsuspected in any of the cereal smuts until that time. Nepal barley was very susceptible to a collection of smut from a hooded nuda variety but immune to some other collections, while Hannchen and Summit were resistant to the collection which infected Nepal but proved very susceptible to other smut collections. Nepal barley was very susceptible to a collection of smut from a hooded nuda variety but resistant to a collection of smut from California and one from Virginia. Summit barley was susceptible to the collection from California but somewhat resistant to the Virginia and nuda collections, while Texas Winter was susceptible to the Virginia collection but resistant to the California and Hannchen collections. Hannchen was very susceptible to the collection upon Hannchen but was somewhat resistant to the other three.

Since this is a matter of some economic importance as well as of considerable scientific interest, the studies have been continued and enlarged,

¹ Brooklyn Botanic Garden Contributions No. 40.

using both fall and spring varieties of barley and a number of collections of the covered smut. Using the collections of smut which have previously (1) indicated physiological specialization, and pure line seed of the host varieties which seemed differential in separating these forms, numerous experiments were carried out under both greenhouse and field conditions, with results as reported below.

SERIES I—GREENHOUSE EXPERIMENTS TO DETERMINE THE DIFFERENTIAL HOSTS FOR FOUR BIOLOGIC FORMS OF THE COVERED SMUT OF BARLEY

Four varieties of barley were inoculated with the smut fungus from several sources and germinated under controlled soil conditions in order to determine which varieties were susceptible to various possible biologic forms. All seed used was pure line material selected from smut free rows of the previous season and was germinated in a neutral soil with a moisture content of 60% of its water holding capacity, in constant temperature tanks at 20° C. After the seedlings had passed through the infection period they were transplanted to the greenhouse benches and kept under favorable conditions for barley until maturity. The methods used were those previously reported (1) in considerable detail and will not be repeated here.

For the sake of brevity in expression the collections of smut which have shown consistent differences in their ability to infect certain varieties of barley are referred to by numbers. To this extent the results of the experiments are anticipated before the presentation of the data.

The data secured in series I are summarized in table 1.

The collections of smut previously reported as indicating physiological specialization again showed the same difference in their ability to infect the several hosts. Hannchen barley was susceptible to the smut originally collected on Hannchen, (here referred to as Form I) but was very resistant to the other three collections. Nepal barley was susceptible only to the smut from *H. nuda* (Form II) and Texas Winter to the Virginia smut (Form IV). Summit barley is susceptible not only to the smut collected in California (Form III), but also to Form I in a lesser degree. Form III can readily be separated from Form I because Hannchen barley is resistant to the former.

SERIES II—SUSCEPTIBILITY OF THE DIFFERENTIAL HOSTS TO FIVE BIOLOGIC FORMS OF THE COVERED SMUT OF BARLEY

Tisdale (6) has recently reported that removal of the hulls is an effective method of securing satisfactory infections in the covered smut of bar-

TABLE 1.—*Greenhouse experiments to determine the differential hosts for four biologic forms of the covered smut of barley*

Seed No.	Variety	Biologic Form of the Smut											
		Form I from Haunchen			Form II from Nepal			Form III From Summit			Form IV from Texas Winter		
		No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	Per cent Inf.
66	Nepal	68	0	0	69	24	34.8	70	0	0	71	0	0
101	Haunchen	75	30	40	76	0	0	76	0	0	76	1	1.3
143	Texas Winter	74	0	0	75	0	0	75	0	0	74	13	17.7
181	Summit	74	21	28.4	70	0	0	74	33	44.6	71	0	0

ley. It then became a matter of interest to see whether or not the removal of the hulls would give high infection in a variety inoculated with spores of a biologic form of the smut which does not infect it under normal conditions. For example, would Hannchen barley become infected by Forms II, III and IV if the hulls were removed? In order to determine this point, as well as to secure additional information concerning the susceptibility of these differential hosts to the smut forms, a series of experiments was carried out in the temperature tanks and in the field. A fifth collection of the smut, which had proved interesting in preliminary trials, was included in these experiments. It has proved readily distinguishable from the other known forms of the smut by infection tests, and, hence, is referred to as Form V.

Four varieties of spring barley were germinated in constant temperature tanks at 10, 15 and 20 degrees centigrade, and after the seedlings had passed beyond the stage when infection is possible, they were transplanted to the field for maturing. The hulls were removed from duplicate sets of the hulled varieties (Hannchen and Summit) before inoculation and run simultaneously with the normal seed. Check field plantings were also made of all these varieties after they had been heavily inoculated with spores of each of the smut forms. Here again the hulls were removed from the hulled varieties and a planting made with such seed inoculated with each of the five forms of the fungus.

The previous fall a planting had been made of Texas Winter barley inoculated by each of these fungous forms. The hulls had been removed from one hundred seeds of this variety before they were inoculated with spores of Form IV of the fungus. The Texas Winter barley was not included in the spring experiments because it will not mature satisfactorily in the spring when germinated at temperatures favorable to high infections, as I have previously shown (1).

The results of this series of experiments are given in table 2.

The small numbers of plants matured in the field sowings of seed from which the hulls had been removed should be noted. Tisdale (6) also records a poor stand with "dehulled" seed sown in the field and suggests that this was due to winter killing. A careful study of this difficulty was made with both winter and spring varieties, the details of which are reported in a later paragraph.

The infection of Hannchen barley by Form I, when the seed was germinated in the temperature tanks and transplanted to the field, are very low. Such low infections have been the rule when winter barleys were germinated in the tanks and transplanted to the field in the fall. As indicated by Table 4, the explanation for this seems to be some peculiarity of the

TABLE 2.—*Susceptibility of the differential hosts to five biologic forms of the covered smut of barley*

Seed No.	Variety	Germinated in	Biologic Form of the Smut									
			Form I		Form II		Form III		Form IV		Form V	
			No. Plants	Per cent Inf.	No. Plants	Per cent Inf.	No. Plants	Per cent Inf.	No. Plants	Per cent Inf.	No. Plants	Per cent Inf.
66	Nepal	Field	116	0	78	48.9	134	0	36	0	127	26.8
		Tank 10° C.	58	0	75	20.0			57	0	66	40.9
		Tank 15° C.	135	0	122	40.2	60	0	130	0	56	62.5
		Tank 20° C.	68	0	54	75.9			52	0	56	73.2
		Total	377	0	329	42.1	194	0	275	0	305	48.2
101	Hannchen	Field	641	40.4	156	0	180	0	43	0	125	6.4
		Tank 10° C.	73	0	72	0			75	0	69	0
		Tank 15° C.	146	1.4	134	0	69	0	136	0	73	0
		Tank 20° C.	44	6.8	43	0			61	0	44	0
		Total	904	29.2	405	0	249	0	315	0	311	2.6
101	Hannchen (hulls removed)	Field	18	88.9	22	0	14	0	23	8.8	16	56.2
		Tank 10° C.	60	75.0	58	0			67	7.5	61	57.4
		Tank 15° C.	92	82.6	134	0	72	0	61	17.2	116	31.9
		Tank 20° C.	20	75.0	39	2.5			37	13.5	52	50.0
		Total	190	80.0	253	.04	86	0	188	12.2	245	43.6
181	Summit	Field	110	11.8	126	0	108	21.3	30	0	131	9.9
		Tank 15° C.	56	32.1	57	0	62	33.9	58	0		
		Total	166	18.9	183	0	170	25.9	88	0	131	9.9

subsequent growing conditions. While this variety was not infected by Form IV, it usually shows 1 or 2 per cent with that form (See table 1). The data are adequate and there seems to be no reasonable doubt that these smut forms are fundamentally different in their infection capacities.

SERIES III—THE INFLUENCE OF THE DATE OF PLANTING UPON THE INFECTION
OF FOUR VARIETIES OF WINTER BARLEY BY FORMS I, II,
AND IV OF *USTILAGO HORDEI*

Field plantings were made at weekly intervals from September 5, to October 25, 1923. Upon each planting date seed of each of four varieties of barley were inoculated with an excess of spores of each of the three forms of the fungus and then planted in 10 foot rows in the experiment field. Great care was taken to prevent mixture of the spores of the biologic forms. The seed grain had been harvested from smut free rows of the 1923 crop, threshed by hand and inoculated. Over 75 per cent of the smut spores of all forms germinated in water and bouillon in 24 hours at room temperature, and practically all of the barley seed was viable in laboratory germination tests.

Hansees Hull-less is a naked, six row, awned, winter barley but is less winter hardy at Brooklyn than the other three varieties. While there was some winter killing in all rows of this variety, the last planting suffered most because the soil temperature remained so low that the plants were but feebly established when the ground was frozen for the winter. Very few plants of the other three varieties, all of which are hulled, six rowed, awned, winter barleys, were lost. In fact, during the three seasons that eighteen varieties of winter barley have been grown in the experiment field of the Brooklyn Botanic Garden, only two varieties, *i.e.*, Nakano wase and Hansees Hull-less, have not been thoroughly winter hardy.

The results of these experiments are recorded in table 3 and summarized in the graph, figure 1.

It is very probable that the soil temperature at the last planting date was so low that it became the limiting factor in the infection by Biologic Form IV, since my previous work demonstrated that a soil temperature of 5° C. practically prevented infection of Hannechen barley by Form I of this fungus. The results of this series of experiments make it quite clear that the four varieties of winter barley used are very resistant to Biologic Forms I and II, and that they are rather susceptible to Form IV. These relations are maintained throughout the varying conditions of soil moisture, temperature, etc., of the entire planting season for winter barley in this locality.

TABLE 3.—*Date of planting experiments, 1923*

Date of Planting	Seed No.	Variety	Biologic Form of Smut								
			Form I			Form II			Form IV		
			No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	Per cent Inf.
September 5	133	Hanseec Hull-less	56	0	0	51	0	0	58	13	22.4
	136	Han River	59	2	3.4	64	1	1.6	87	19	21.9
	142	Tennessee Winter	66	0	0	69	0	0	83	13	15.7
	143	Texas Winter	68	0	0	73	0	0	91	20	21.9
September 12	133	Hanseec Hull-less	68	1	1.5	70	0	0	78	17	21.8
	136	Han River	70	0	0	76	0	0	88	22	25.0
	142	Tennessee Winter	75	0	0	91	0	0	92	12	13.0
	143	Texas Winter	83	0	0	89	0	0	92	16	17.4
September 19	133	Hanseec Hull-less	100	0	0	70	0	0	50	15	30.0
	136	Han River	111	0	0	120	0	0	73	22	30.1
	142	Tennessee Winter	101	0	0	118	0	0	81	12	14.9
	143	Texas Winter	106	0	0	115	0	0	92	17	18.5
September 26	133	Hanseec Hull-less	73	0	0	93	1	1.1	138	28	20.3
	136	Han River	141	0	0	118	0	0	152	41	26.9
	142	Tennessee Winter	147	0	0	127	0	0	146	19	13.0
	143	Texas Winter	186	0	0	196	0	0	122	33	27.0

TABLE 3.—(Continued)

Date of Planting	Seed No.	Variety	Biologic Form of Smut											
			Form I				Form II				Form IV			
			No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	Per cent Inf.	No. Plants	No. Inf.	No. Plants	No. Inf.	Per cent Inf.	Per cent Inf.
October 4	133	Hanse Hull-less	45	0	0	48	0	0	38	15	38	15	39.5	
	136	Han River	100	0	0	105	1	0.9	81	19	81	19	23.5	
	142	Tennessee Winter	96	0	0	93	0	0	89	9	89	9	10.1	
	143	Texas Winter	91	0	0	86	0	0	78	12	78	12	15.4	
October 11	133	Hanse Hull-less	48	0	0	54	0	0	45	14	45	14	31.1	
	136	Han River	95	0	0	96	0	0	91	32	91	32	35.2	
	142	Tennessee Winter	90	0	0	80	0	0	108	17	108	17	15.7	
	143	Texas Winter	93	0	0	92	0	0	92	22	92	22	23.9	
October 18	133	Hanse Hull-less	30	0	0	36	0	0	17	7	17	7	41.2	
	136	Han River	75	0	0	78	0	0	74	8	74	8	10.8	
	142	Tennessee Winter	86	0	0	78	0	0	67	11	67	11	16.4	
	143	Texas Winter	80	0	0	83	0	0	75	15	75	15	20.0	
October 25	133	Hanse Hull-less	45	0	0	60	0	0	22	3	22	3	13.6	
	136	Han River	75	0	0	78	0	0	74	0	74	0	0	
	142	Tennessee Winter	75	1	1.4	86	0	0	81	0	81	0	0	
	143	Texas Winter	80	0	0	82	0	0	88	0	88	0	0	

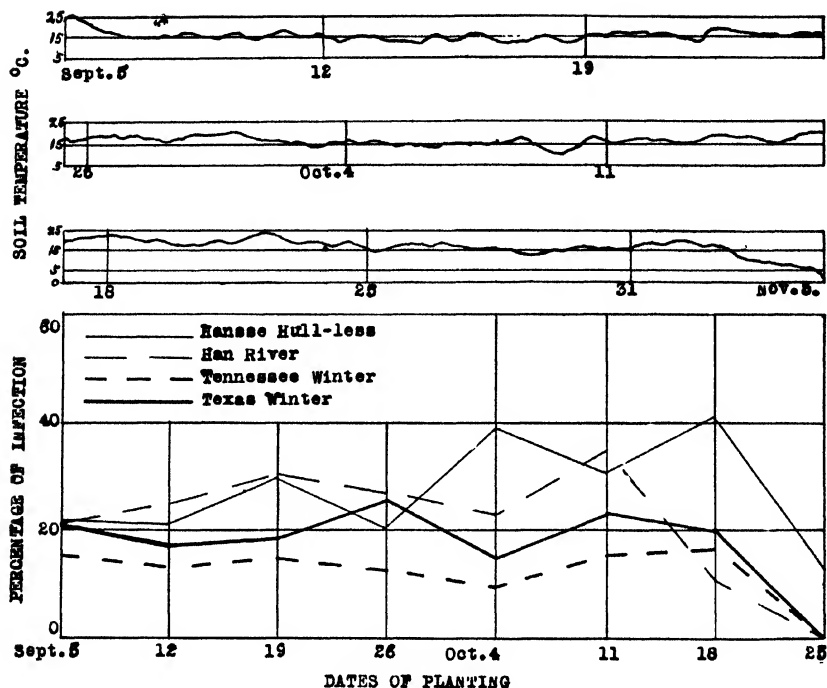


FIG. 1. *Top*—Soil thermograph records from September 5 to November 5, 1923, reduced to one fourth the original size by a pantograph. *Bottom*—Graph showing the percentages of infection of four varieties of winter barley by Form IV of *Ustilago hordei*.

The temperature and moisture records for the season also indicate that these factors greatly influenced the amount of infection by Form IV secured at the various seeding dates. The first planting was made in a dry soil, the second and third in a medium dry soil, the fourth in a soil with a moisture content between 60 and 70 per cent of the moisture holding capacity. The plantings for October 4, 11, and 18 were made in a soil with a moisture content of 40 to 50 per cent, while the last planting was made in a rather wet soil. The soil reaction is between pH 7 and 7.2. The soil temperature fluctuations are shown in the broken graph at the top of figure 1. This graph was made by reducing the weekly soil thermograph records with a pantograph to one fourth of their actual size. All plantings were germinated at temperatures well within the range for high infection (10°C. – 25°C.) except the last one made on October 25, which had not emerged before the soil temperature dropped to freezing.

Considering the interaction of these factors and their probable result, these dates of planting experiments are entirely in accord with the results

of the controlled experiments previously reported (1). A certain amount of fluctuation in field plantings is inevitable due to unevenness of the soil, manuring, moisture distribution, etc.

SERIES IV—THE INFLUENCE OF GROWTH CONDITIONS SUBSEQUENT TO THE INFECTION PERIOD UPON THE DEVELOPMENT OF COVERED SMUT

To determine the influence of growth conditions subsequent to the infection period upon the development of this smut, two varieties of winter barley were inoculated with spores of Forms I, II and IV, as in series II, and then germinated in the temperature tank at 20° C. in a neutral soil with a moisture content of 60 per cent of its moisture holding capacity. After these seedlings had passed beyond the stage where infection is no longer possible, they were divided at random and one half planted in the field, the other half in the greenhouse. That is, the conditions during the infection period were the same for both sets of plants and any marked differences in the amount of disease in the final crop must be due to influences of growth after transplanting. The seeds were planted in the tank October 13 and the seedlings were transplanted to the field and greenhouse bench on October 20. The results are given in table 4.

The barley in this series of experiments was planted rather late to avoid the excessively high temperatures of the greenhouse. Because of this late planting some of the seedlings in the field were lost. These results indicate that certain growing conditions after the infection period may have a great deal to do with the amount of covered smut appearing in the final crop. I have reported (1, series III) an experiment in which a number of seedlings were germinated under the same environmental conditions and then divided, one half being matured in a neutral soil and the other half in a strongly acid soil. The plants grown in the acid soil were badly stunted, while the others made vigorous growth, yet there were no marked differences in the percentages of infection. Quite a different set of conditions were under consideration in the present experiment, however, and it would be difficult to say that either the set matured in the greenhouse or that grown in the field was the more vigorous.

It is hard to determine just what factors operated to prevent the development of Form IV of the fungus in the plants matured in the field. It is significant, however, to find that development of the smut may be inhibited after the fungus has penetrated the seedling of a susceptible host, as certainly must have been the case with Form IV of this fungus. The conditions presented in this experiment are very extreme. The plants matured in the greenhouse made uninterrupted growth while those in the field went through the winter "rest period" as do all fall sown grains in

TABLE 4.—*The influence of growth conditions after the infection period upon the development of covered smut of barley*

Seed No.	Variety	Smut Form I					Smut Form II					Smut Form IV				
		No. Plants	No. Smutted	No. Par. Smutted	Per cent Inf.	No. Plants	No. Smutted	No. Par. Smutted	Per cent Inf.	No. Plants	No. Smutted	No. Par. Smutted	Per cent Inf.			
Matured in Greenhouse	136 Han River	73	0	0	0	71	0	0	0	72	25	3	38.8			
	143 Texas Winter	74	0	0	0	75	0	0	0	74	9	4	17.5			
Matured in Field	136 Han River	55	0	0	0	59	0	0	0	60	0	0	0			
	143 Texas Winter	72	0	0	0	59	0	0	0	69	0	0	0			

TABLE 5.—*Influence of removal of the hulls upon infection by covered smut of barley*

Where Matured	Seed No.	Variety	Normal Seed				Seed with hulls removed			
			No. Plants	No. Smutted	No. par. Smutted	Per cent Inf.	No. Plants	No. Smutted	No. par. Smutted	Per cent Inf.
Greenhouse	101	Hannchen	75	29	1	40.	68	56	3	86.8
"	143	Texas Winter	74	9	4	17.7	58	53	0	91.3
"	181	Summit	74	31	2	44.6	46	42	1	93.5
Field	127	Omar	82	0	1	1.2	22	5	1	27.2
"	129	Swan Neck	66	2	1	4.5	21	4	3	33.3
"	135	Greece	59	3	2	8.4	33	18	3	63.6
"	136	Han River	86	25	6	36.	14	5	2	50.
"	142	Tenn. Winter	92	10	7	18.4	24	12	1	54.1
"	143	Texas Winter	76	20	5	32.9	18	15	0	83.3
"	145	Wisconsin Winter	72	6	2	11.1	8	1	0	12.5

this climate. The possibility that the conditions of growth of the hosts, after the smut has penetrated the seedling, may influence the percentage of disease in the crop may account for widely divergent results secured in different years, when the soil temperatures and moistures at seeding time would seem to be within ranges to give fairly consistent results. It should be pointed out that the reaction of barley varieties to such environmental changes may not be the same. The growth factors which operated to give very low infections in normal seed of Hannchen barley inoculated with Form I of the fungus as reported in the tank experiments of table 2, did not have a like effect upon Nepal barley inoculated with Form II. Our meager knowledge of the phenomena which may influence the development of the smut after the penetration of the seedling would seem to warrant a series of studies of such problems under controlled light, moisture and temperature throughout the development of the host.

SERIES V—THE INFLUENCE OF REMOVAL OF THE HULLS UPON THE INFECTION AND GROWTH OF BARLEY

Seven varieties of winter barley, all more or less susceptible to Biologic Form IV of the fungus, were planted in 10 foot rows in the experiment field October 3, 1923. The hulls were removed from one hundred seeds of each variety, and they were heavily dusted with spores of Form IV of the fungus. A check row was treated in exactly the same manner, except that the hulls were not removed. These two lots of each variety were planted in adjacent rows. Duplicate seed lots of Hannchen inoculated with Form I, of Summit with Form III, and of Texas Winter with Form IV, were treated in a like manner except that they were germinated in a neutral soil at 60 per cent of its moisture holding capacity and matured in the greenhouse. Only 75 seeds were used in each lot in these greenhouse experiments. The results are recorded in table 5.

The results of this planting confirm those reported by Tisdale (6) upon the infection of winter barley by covered smut in that the percentages of infection were increased by removing the hulls from the seed before inoculation. Tisdale's results were secured in the greenhouse, his field experiments having failed, "due to almost complete winter-killing of plants from dehulled seed." The numbers of plants in my field plantings (Table 5) were also greatly reduced when "dehulled" seed were used. By examination of the rows from time to time it was learned that while practically all the seed from which the hulls had been removed germinated, only a small percentage was able to reach the soil surface. Those which did emerge from the soil were apparently as winter hardy as the adjacent row of normal seed. In many cases such a barley plant is unable to reach the soil sur-

face and the young leaves grow for a time in a twisted, contorted manner, develop a sickly, yellowish-green color, but soon die.

Those plants which reach the surface in a reasonable length of time seem to develop normally. The first leaves are often thicker and in some cases the germination stages up to the development of the third leaf were more advanced in the seed from which the hulls had been removed than in the normal seed. This difficulty was largely overcome in the greenhouse plantings by germinating the seed in the temperature tank and upon transplanting them, straightening out each seedling. This same method was used in series II but, even when this was done, some of the seedlings were lost.

It should be emphasized, however, that in no case was I able to get higher infections under these conditions by removing the hulls from the seed of Hannechen barley (Tables 2 and 5) than I have previously reported (1) for this variety when the hulls were not removed but environmental conditions more favorable for the smut were used. The infections secured with Hannechen barley under the controlled conditions as reported in tables 1, 5 and 6 compare very favorably with those secured at the same soil temperature and acidity in my previous experiments. The removal of the hulls, while effective in securing high infections, creates favorable conditions for the smut which can readily be duplicated by other means, such as those described in my previous paper (1, page 204, tables 3 and 4).

I have no doubt, however, that in farm practice injury to the hull over the seed embryo may play a part in the amount of loss from this barley smut. In fact, I have received field threshed barley with a considerable proportion of the seed as effectively dehulled by close threshing as could be done by hand. Using such grain for seed would not only increase the likelihood of smut loss, but the stand in the field would be much thinner than if uninjured grain were used. In my field plantings of seed with the hulls removed the latter loss was far greater than the smut loss (see table 5).

ENVIRONMENTAL RELATIONS

In a previous report (1) the influences of temperature and acidity at two soil moistures were discussed. The character of the substrata during the period of infection, and wider ranges of soil moistures have been made the basis for further experiments.

SERIES VI—THE INFLUENCE OF THE CHARACTER OF THE SUBSTRATA AND THEIR
MOISTURE CONTENT DURING GERMINATION UPON THE INFECTION
OF NEPAL AND HANNCHEN BARLEY BY COVERED SMUT

For this series of experiments, two varieties of barley with two forms of the fungus have been used. Nepal, a six-rowed, hooded, naked barley was inoculated with Form II and Hannchen, a two-rowed, awned, hulled barley was inoculated with Form I. These were germinated in the constant temperature tanks at 20° C. In one set of experiments a pure quartz sand, graded to pass through a 20 but not a 30 mesh sieve, was used, and in the other set a good rich potting soil was used. After the period of infection both sets of experiments were transplanted to the greenhouse bench. The results are recorded in table 6.

In both varieties the percentages of infection were much lower when the seeds were germinated in the quartz sand than they were when the neutral potting soil was the medium. The lower moistures of the neutral soil were more favorable for infection than were the higher moistures, a condition noted in my previous report. Lower soil moistures were not used because the seeds would not germinate and higher soil moistures were omitted because of the difficulty of handling soil with a moisture content above 70 per cent of its water holding capacity. The low infections secured in the quartz sand are quite similar to results secured in extensive experiments with covered smut upon both winter and spring varieties of barley when builders sand was used. On the other hand this same builders sand proved quite satisfactory for use with the smuts of oats and sorghum, as reported by Reed and Faris (4, 5).

In view of the low percentages of wheat bunt secured by Heuser (2) in plots treated with nitrogen and complete fertilizers as compared with those secured in plots treated with phosphoric acid, potash and untreated, it would be interesting to carry out a series of experiments in which various nutrients were added to this quartz sand to determine the influence of different fertilizer materials upon infection of barley by *Ustilago hordei*.

Like soil temperature and soil acidity, the soil moisture range for high infection covers all the ordinary moisture conditions for field planting, as it is quite unlikely that barley would be planted in a soil as dry as 20 per cent nor as wet as 70 per cent of its moisture holding capacity.

SERIES VII—THE INFLUENCE OF THE HOT WATER SEED TREATMENT PRIOR TO
INOCULATION UPON THE PERCENTAGE OF SMUT IN THE CROP

A quantity of seed of two varieties of barley, Hannchen and S. N. 349, a hooded, naked six-rowed variety, was presoaked in tap water for eight hours and then immersed for 13 minutes in water heated to 52° C. After

thoroughly drying, the seed of Hannchen was inoculated with Form I, and that of S. N. 349 with Form V of the fungus. Lots of untreated seed of each variety were likewise inoculated with the respective biologic forms. A row of treated seed was planted beside a row of untreated seed, and these plantings were repeated at five different places in the experiment field for each variety. All plantings were made the same day, April 5, 1924. The results are summarized in table 7.

The percentages of infection, based upon the totals, are so close that there is no indication that the seed treatment had any appreciable effect upon the amount of smut. A measured amount of seed was used in each row and the smaller number of plants which were matured in the treated rows indicates that there was some seed injury from the treatment.

DISCUSSION AND CONCLUSIONS

That the covered smut of barley is made up of several biologic forms, as suggested in my previous report (1), is here demonstrated beyond reasonable doubt, and the differential hosts for five forms of the fungus are given. I have referred to these biologic forms by a form number, thus adopting the method used by Dr. E. C. Stakman and his co-workers in differentiating the biologic forms in the cereal rusts.

The infection relations of these five forms to their differential hosts may be summarized as follows:

Seed No.	Variety	Form I	Form II	Form III	Form IV	Form V
66	Nepal .	R	S	R	R	S
101	Hannchen	S	R	R	R	S
181	Summit	S	R	S	R	S
143	Texas Winter	R	R	R	S	R
		R = Resistant		S = Susceptible		

Form I infects Hannchen and Summit, Form II infects Nepal, Form III infects Summit, Form IV infects Texas Winter and Form V infects Nepal, Hannchen and Summit.

Each of these varieties has been inoculated with each smut form and germinated under a variety of enviroinal conditions. Their resistance to forms, other than those to which they are listed as susceptible, has been maintained, thus demonstrating that the smut forms are biologically different in their capacity to infect.

The results of preliminary experiments, in which more than 100 varieties of barley were inoculated with smut collections from many localities, indicate that there exist still other biologic forms of this smut. More

TABLE 7.—*The influence of hot water treatment upon the percentage of smut in subsequently inoculated seed*

Planting No.	Hooded beardless barley (S. N. 349) inoculated with smut form Y							Hamchen barley (S. N. 101) inoculated with smut form I						
	Seed untreated				Seed treated with hot water			Seed untreated				Seed treated with hot water		
	No. Plants	No. Smutted	No. Par. Smutted	Per cent Inf.	No. Plants	No. Smutted	Per cent Inf.	No. Plants	No. Smutted	No. Par. Smutted	Per cent Inf.	No. Plants	No. Smutted	Per cent Inf.
1	61	7	5	19.6	33	8	2	85	18	24	49.4	64	7	19
2	37	10	9	51.3	26	3	5	80	7	26	41.2	77	6	18
3	46	6	6	26.0	28	4	3	91	11	23	31.3	73	12	18
4	74	19	7	35.1	50	11	1	65	6	25	47.6	64	5	26
5	73	18	2	27.4	44	14	1	103	13	30	41.7	93	3	27
Total	291	60	29	30.5	181	40	12	424	55	128	43.1	371	33	108
							28.7							38.0

experimental work is necessary before the relation of these probable forms to the differential hosts of the above five forms can be stated, however.

In view of the finding of biologic forms in the covered and loose smuts of oats which has been reported by Reed (3), and the above results with the covered smut of barley, it would seem quite likely that other smut fungi are specialized into biologic forms. Since some host varieties are susceptible to more than one biologic form of a fungus (*i.e.*, Summit barley to Forms I, III and V), the possibility that smutted heads of such a variety collected in the field may contain a mixture of forms should not be overlooked in experimenting with this disease. It becomes very important to have not only authentic seed of the barley varieties, but also to know something of the host relations of the fungous material to be used, before extensive experiments with this disease are undertaken. A diligent search should also be made with other smut species in order to determine whether or not specialized races exist in them.

ENVIRONMENTAL RELATIONS

The date of planting experiments, in which four varieties of winter barley inoculated with Forms I, II and IV of the covered smut fungus and planted at weekly intervals during the fall of 1924, indicate that the soil conditions became more favorable for infection from early September to late October, at which time the cold soil temperatures became the limiting factor in infection with Form IV of the parasite. These barley varieties maintained their resistance to Forms I and II of the fungus at all of the various planting dates.

There are considerable data in tables 2 and 4, which indicate that growth conditions after the infection period may have a very marked effect upon the percentage of smut which finally appears in the crop.

The "dehulling" of the seed, either by hand or by close threshing, may increase not only the likelihood of smut infection but may be a source of even greater loss because of a poor stand of barley.

The character of the soil has proven to be of considerable importance in securing satisfactory infections with covered smut. Quartz and builders sand have been found poor substrata for securing high infections and in this respect this disease has proven quite different from the smuts of oats and sorghum reported by Reed and Faris (4, 5).

The results of the moisture studies reported in table 5 indicate that high infections may be gotten over wide ranges of soil moisture. As pointed out previously (1), the final amount of disease appearing in the crop is the result of the interaction of many factors. The present results serve to emphasize that the factors limiting infection may be environal or

biologic and may exert their influence upon the parasite or the host or the parasite relation between the fungus and the host.

The treatment of the seed grain by hot water before inoculation with the fungous spores, had no appreciable effect upon the percentage of smut secured in the field plantings reported in series VII. It would seem, therefore, that experimental results secured with seed treated by hot water would be comparable to results from smut free seed which had not been treated.

The writer is indebted to Dr. G. M. Reed, Curator, Brooklyn Botanic Garden, for many valuable suggestions during the course of this work; and to Prof. R. A. Harper, who generously permitted the use of some of his private grounds for carrying out the extensive preliminary experiments.

LITERATURE CITED

1. FARIS, J. A. Factors influencing infection of *Hordeum sativum* by *Ustilago hordei*. Amer. Jour. Bot. 11: 189-214. Pl. 7-8. 1924.
2. HEUSER, W. Versuche über den Einfluss äusserer Bedingungen, auf die Stärke des Steinbrandbefalles des Weizens. Fühl. Landw. Zeitg. 71: 81-99. 1922.
3. REED, G. M. Physiologic races of oat smuts. Amer. Jour. Bot. 11: 483-492. 3 fig. 1924.
4. REED, G. M., and J. A. FARIS. Influence of environal factors on the infection of sorghums and oats by smuts. I—Experiments with covered and loose kernel smuts of sorghum. Amer. Jour. Bot. 11: 518-534, 1924.
5. —————. Influence of environal factors on the infection of sorghums and oats by smuts. II—Experiments with covered smut of oats and general considerations. Amer. Jour. Bot. 11: 579-599, 1924.
6. TISDALE, W. H. An effective method of inoculating barley with covered smut. Phytopath. 13: 551-554. 1923.

· PATHOLOGIC HISTOLOGY OF APPLE BLOTCH

E. F. GUBA

WITH PLATES XXX AND XXXI AND FIVE FIGURES IN THE TEXT

The history of the *Phyllosticta* apple blotch, caused by *Phyllosticta solitaria* E. & E., began with collections of this disease by Underwood (7) from Crawfordsville, Indiana, in 1893, on the leaves of the native American crab apple (*Pyrus coronaria* L.) and by Clinton (1) from southern Illinois in 1902 on the fruit of the commercial apple (*Pyrus Malus* L.). In 1920 Roberts (3) presented a brief account of the pathologic histology of apple blotch cankers. To the knowledge of the writer this appears to be the only published account on this subject. The object of this paper is a further and more extensive consideration of the pathologic histology of this disease. The main results of the investigation, already published in abstract form, will appear in print subsequently.

When this study was undertaken it was hoped to determine the mode of entrance of the fungus into the healthy tissues and the morbid changes in the tissues immediately following infection. Unfortunately, these points have not been solved by this study for reasons which may be briefly enumerated here. Spore production in culture of species of the genus *Guignardia*, to which, no doubt, *Phyllosticta solitaria* belongs, appears to be a rare occurrence, this being decidedly so of *Phyllosticta solitaria*. In the absence of a supply of spores from pure culture, artificial inoculations of the host with spores from this source were not possible. Efforts were made to inoculate the host with spores from apparently mature fruiting bodies obtained from lesions on the host but the spores from these sources when available and when needed generally failed to germinate. Scott and Rorer (5) (6) report having obtained successful artificial inoculation in the orchard with spores obtained from natural sources, but their results are open to criticism since the inoculated parts were exposed to natural infection and spores from pure culture were not used. Roberts (4), however, established the pathogenicity of the fungus with spores from pure culture. The accounts of his results are presented rather briefly without affording any definite conclusions regarding spore production in culture or regarding infection. No one has yet determined the manner in which infection takes place. The problem of spore production in culture and artificial infection with spores warrants investigation. In view of the writer's failure to obtain artificial infection, certain points of interest in the pathologic histology of the disease could not be determined. This account, there-

fore, is largely based on the gross histology of affected tissues as revealed in microscopic sections.

IN THE TWIGS

The anatomy of the normal bark of one year old apple twigs in transverse section reveals the cuticle, epidermis, cork layers, a compact, rather broad band of collenchyma of four tiers of cells and a loose spongy parenchyma with many intercellular spaces (Plate XXX, fig. B). Strands of sclerenchyma are located deep in the spongy parenchyma, that is, in the pericyclie region, and beyond them are evident the medullary rays. Within the sclerenchyma and between it and the cambium is the phloem. Frequently in the young twigs individual strands of sclerenchyma are united to form an unbroken irregular sheath of sclerenchyma around the phloem and the terminations of the medullary rays.

A transverse section through diseased bark reveals necrosis extending to a point midway between the epidermis and the cambium. The diseased tissues are separated from the healthy, directly beneath the sclerenchyma,

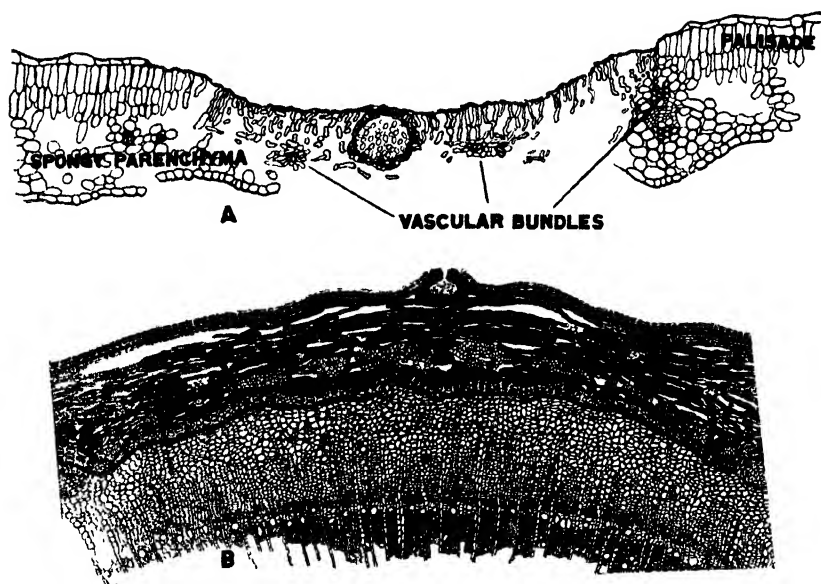


FIG. 1. A. Section through a leaf spot showing the central position of the pycnidium, the dead palisade cells hanging loosely from the collapsed epidermis, the mass of dead parenchyma cells around the vascular bundles, and the compact mass of living cells across the mesophyll at the vascular bundle. B. Section through a canker on a water sprout showing the necrotic region on the outside, the cork cambium, and the dense underlying region of small parenchyma cells (phelloderm). From material collected November 10, 1919.

by a compact cork layer of two to three tiers of cells (Fig. 1, B). Directly outside of this cork cambium is a compact sheath of dark colored cells. The formation of periderm by the cork cambium occurs rapidly. Phellem production is limited to a few layers of cells while, to the inside, phelloderm production is very marked (Plate XXX, fig. A and C). Coincident with the formation of periderm the cambium layer is stimulated in places to rapid formation of parenchyma (Plate XXX, fig. A) instead of normal phloem. The phelloderm is composed of small round cells arranged in compact radial columns (Fig. 1, B) and the medullary rays which extend out through the phelloderm to the cork cambium are distorted and composed of small cells.

The mycelium is intercellular and generally present outside of the abscission layer and its development appears to be most extensive in the collenchyma. The fungus does not come into contact with the phloem, medullary rays and cambium although these tissues appear to be markedly affected indirectly as the result of the necrosis of the outer cortex. Between the lower tiers of cells of the collenchyma and the outermost tiers of cells of the spongy parenchyma, small knots of mycelium are evident, these later developing into pycnidia or pycnosclerotia according as they are formed early or late in the season.

In August and September when the new cankers first became evident and during the course of the following dormant season the diseased parenchyma cells outside of the periderm still appear to be living. The growth of the cankers is to a large extent inhibited during the dormant season. Cracks are formed in the fall especially along the longer margins of the cankers, which in transverse section appear just outside the periderm (Plate XXX, fig. C). The growth of the fungus occurs actively again early in the spring and, as a result, the cells within the invaded region are killed. The presence of the protective layer and the complete isolation of the necrotic tissues, with the resulting exposure of these tissues to desiccation, probably also plays an important part in the death of the cells.

New cankered areas appear along the margins of the old cankers. Whether the fungus is already present in the parenchyma beyond the cork cambium and merely continues its growth when favorable conditions permit or whether it penetrates the periderm and infects the healthy tissues beyond it early in the season has not been determined. In Illinois the growth of the fungus and the formation of new cankered areas appear to be most marked early in the spring and early in the fall. The necrosis of the outer cortex and the formation of cork cambium layers below the sclerenchyma continue for some years. The cankered areas become rifted at the margins (Plate XXXI, fig. D) and by being marked with different shades of brown appear

distinct from other portions of the canker. The dead tissues are gradually exfoliated (Plate XXXI, fig. B) thus exposing the cork cells or phellem. The increase in the number of cells between the cork cambium and the cambium as the result of the activity of these meristematic tissues and their growth in size and differentiation continues until the wound is repaired.

It is apparent from the foregoing account and the study of plate XXX, fig. A and figure 1, B that the fungus may be readily removed from the bark with a knife by cutting away all of the discolored tissues. This exposes the fresh healthy phloem between the abscission layer and the cambium and the rapid formation of new phloem by the cambium eventually repairs the wound.

IN THE PEDICELS

A transverse section of the cortex of a normal apple pedicel shows on the outside a thin cuticle, then a narrow epidermis, surmounting a much broader layer of collenchyma of about four to five tiers of cells and next spongy parenchyma of large cells and intercellular spaces. Beyond the parenchyma are regions of sclerenchyma which are united more or less into broad irregular bands around the phloem and the terminating cells of the medullary rays.

The pathologic histology of the pedicel in transverse section generally appears to be similar to that of the twigs (Fig. 2). The necrosis of the pedicel extends midway into the parenchyma. Here, however, the protective layer forms outside of the sclerenchyma sheath rather than inside as was found to be the case in the twigs. The cells of the protective layer are commonly round or broad and elongate with truncate ends exposed to the necrotic area and their walls and contents are brown. There is no indication of the formation of phelloderm or of the presence of a cork cambium. It appears that individual cells of the spongy parenchyma between the protective layer and the sheath of sclerenchyma have divided to account for hyperplasia in this region. Outside of the protective layer the tissues are collapsed and desiccated. This layer prevents drying, affords mechanical protection and hinders the invasion of the underlying parenchyma by the pathogene.

The mycelium is generally distributed throughout the necrotic tissue although most extensively developed in the collenchyma where necrosis occurs at a more rapid rate than in the parenchyma directly beyond. Pycnidia are formed between the upper tiers of cells of the collenchyma or directly below the epidermis.

IN THE FRUIT

The healthy apple when studied in transverse section shows a thick cuticle lying over an epidermis composed of irregular polygonal cells. Below the epidermis lies the hypodermis of about 4 to 5 tiers of cells. The ultimate branchlets of the vascular bundles approach the hypodermis. Beyond, extending to the primary vascular bundles, is a much broader region of spongy parenchyma which with the hypodermis comprise the "cortex" or the outer pericarp. Ten primary vascular bundles lie in a circle about midway between the central cavity and the epidermis and mark the division between the cortex and the "pith" or inner pericarp. The pith is comparatively narrow, composed of spongy parenchyma extending to the endocarp. It is distinguishable from the cortex by the absence of vascular tissue and by the longer, narrower cells.

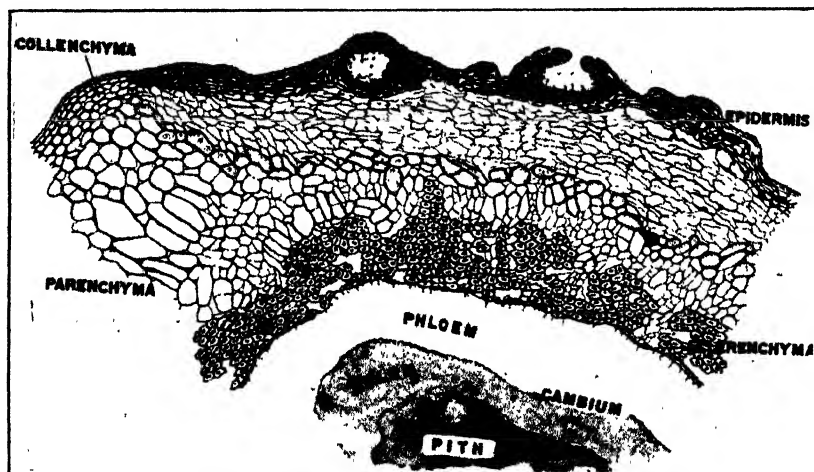


FIG. 2. Section through an affected pedicel. The living and dead areas are separated by a definite protective layer of dark colored cells; below in the parenchyma tissue and outside of the sclerenchyma the tissue is compact and composed of small irregular shaped cells.

The different varieties of apples usually manifest different symptoms of apple blotch which may be classified according to their external appearance as: the pitted; the blistered; and the fringed blotch types. The lesions of the fringed blotch type are radiate and feathery with fringed margins. This type may be found on the Northwestern Greening, Maiden Blush, Yellow Transparent, and Duchess varieties. The pitted type is characterized by sunken areas with definite and distinct borders; it appears to be

common on the Jonathan, Missouri Pippin, Ben Davis, Arkansas Black, and McAfee varieties. This type is excellently illustrated by Lewis (2). The fringed blotch type precedes or sometimes surrounds the pitted areas as they enlarge. The occurrence of deep rifts across the blotches appears to be common to the fringed blotch type. In contrast to the hard and superficial qualities of the lesions of the fringed type, the lesions of the pitted type are deeper and the tissue is soft although also dry. The early stages of apple blotch are usually all of the fringed type; later as the fruit matures some portions become pitted while other portions remain distinctly feathery and spreading. The third type is manifested in the form of blisters with partly cracked margins. This type appears to be common on the May of Meyers and the Benoni.

From a histological study of the affected tissues of apples exhibiting these types of blotch it appears that the reaction of the host cells to the invading fungus is responsible for differences in the symptoms. These different types of apple blotch appear to be quite characteristic of certain varieties. It seems logical to believe that they are the result of differences in the growth of the apple peculiar to the variety rather than of different strains of fungus.

a. Fringed Type of Apple Blotch

In the fringed type of apple blotch, necrosis is confined to the epidermal and hypodermal cells. The spongy parenchyma cells directly beyond apparently are not affected. Growth of the apple below the affected portion is stunted while the tissues around the necrotic region continue growth and, as the result, create opposite stresses. The necrosis of the cells of this outer region of the fruit also unduly exposes the tissues to drying. As the result of these abnormal conditions cracks form across the surface of the blotch. The crack at first is broadly wedge-shaped and extends into the hypodermis. In the lower hypodermis the cells are brown and are arranged very compactly. In the spongy parenchyma broken cell walls and radially elongate cavities are evident and ultimately, the crack extends deep into the pith. The cells of the spongy parenchyma adjacent to the rifts become torn and radially elongate, and greatly distorted about the bundles.

b. Blistered Type of Apple Blotch

The lesion is quite superficial, confined to the hypodermis and epidermis and limited radially by the formation of distinct periderm directly below the hypodermis (Fig. 3). Directly outside of the periderm is a protective layer of compactly arranged round, dark colored cells. The abscission region inhibits the progress of the fungus radially into the spongy paren-

chyma, although tangentially the fungus grows slowly along the hypodermis causing necrosis of the cells. The raised blistered blotches result from active growth of the cork cambium, giving rise to a broad, compact mass of small cells, the phelloderm, arranged in radial columns. The amount of phellem produced is comparatively insignificant. The epidermis is sometimes broken at the margins of the blotches. As desiccation progresses, the collapsed, discolored cells become more or less separated from the abscission layer.

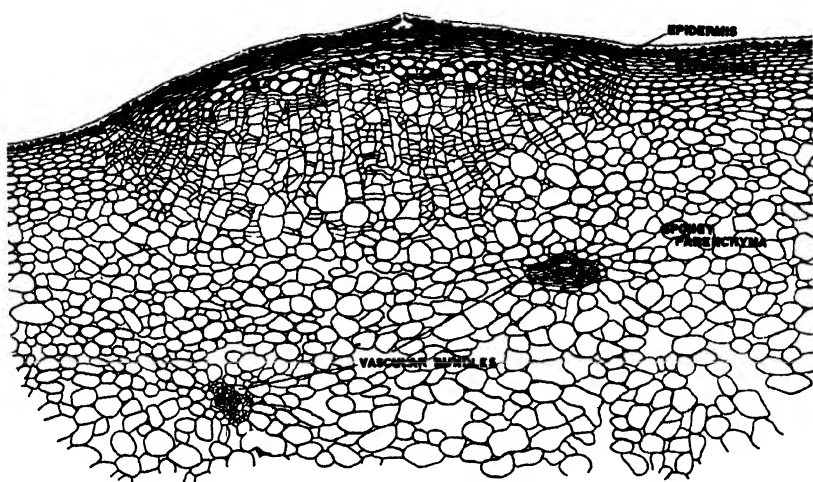


FIG. 3. Section through an apple affected with the blistered type of apple blotch showing the distinct protective layer of large, round, dark colored cells and the periderm layer dividing the living and dead tissues. The dense columnar arrangement of the cells of the phelloderm and their marked multiplication in number is very distinct of this type of apple blotch.

c. *Pitted Type of Apple Blotch*

A marked contrast between the pitted type and the blistered type of apple blotch is indicated by the absence of a distinct abscission layer between the dead and living tissues and in the presence of large cavities in the cortex directly beyond the hypodermis (Fig. 4). Necrosis extends deep into the cortex below the outer vascular bundles. The epidermal and hypodermal cells are collapsed, these tissues together forming a dense, collapsed, region. Below in the spongy parenchyma the cell walls are torn apart, and in the corners of the dead cells masses of starch grains are evident, their formation being the result of disease.

The dead pitted region is sometimes definitely surrounded by normal spongy parenchyma, hypodermal and epidermal cells. Usually the pitted

area is surrounded by an area of blotch of the fringed type, in which case the hypodermis and the epidermis only are affected. The pitted region is dry but soft, due to the large open spaces in the cortex.

The intercellular mycelium is extensively developed directly beyond the epidermis and extends loosely among the cells of the hypodermis and partly into the spongy parenchyma. It is entirely absent deep in the affected cortex. The pycnidia form directly below the epidermis and commonly between the upper tiers of cells of the hypodermis.

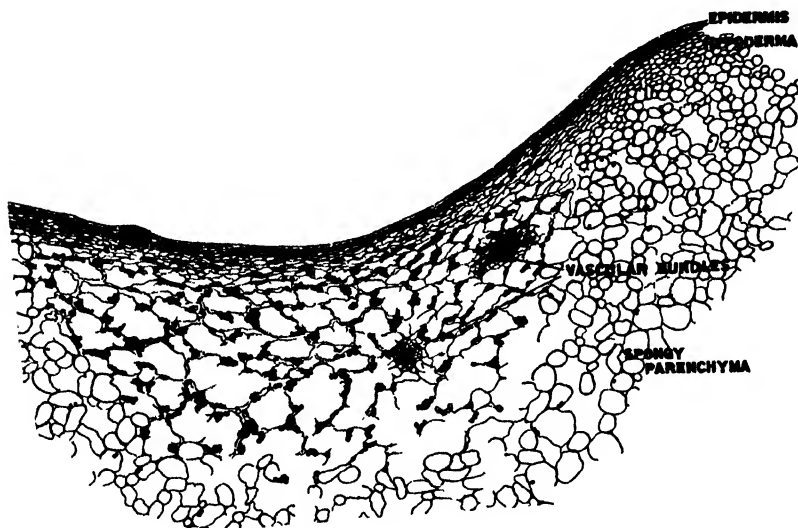


FIG. 4. Section through an apple blotch pit from the Jonathan apple showing the characteristic large, open cavities, the loose broken cell walls in the spongy parenchyma, and starch grains in the cells of the affected region. The living and dead tissues are not separated by a protective layer.

IN THE FOLIAGE

In the Blades

The spots are sunken on the upper surface, and in transverse section the thickness of the leaf is reduced usually to about one-half of the normal (Fig. 1 A). The bundles seem to offer some obstruction to the progress of the fungus. The healthy and dead areas are usually separated by a compact mass of parenchyma cells reaching across the mesophyll, near a vascular bundle. The usually solitary pycnidium occupies a central position on the upper surface of the spot (Plate XXXI, fig. A).

The mycelium is intercellular and ramifies loosely among the palisade tissues and parenchyma cells. It appears to be most extensively developed

below the upper epidermis from which strands extend among the cells of the mesophyll. Infection is followed by the development of a mass of mycelium directly below the epidermis and in the palisade tissue which leads to the formation of the pycnidium. As the pycnidium develops, the dead palisade cells are crushed and pushed aside and the epidermis is raised and ruptured. The upper epidermal and palisade cells collapse as the fungus advances and later the cells of the spongy parenchyma and lower epidermis succumb. The palisade cells become distorted and hang loosely from the dead collapsed epidermis, while those of the spongy parenchyma separate, or are grouped in small masses about the vascular bundles. Occasionally, portions of the lower epidermis and spongy parenchyma fall away, exposing the palisade cells above.

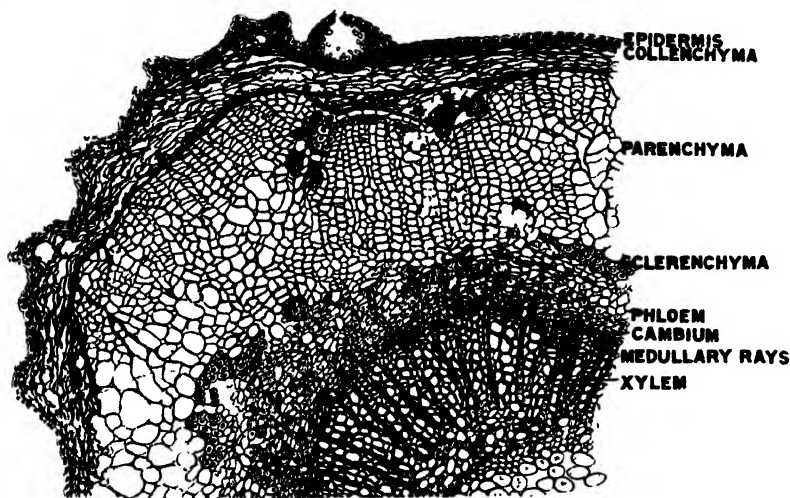


FIG. 5. Section through a petiole showing the effect of the fungus upon the tissues, the dead outer region of the cortex, the abscission layer and the dense columnar arrangement of the parenchyma cells beneath where marked hyperplasia is evident. Strands of sclerenchyma have been pushed out along the abscission layer.

In the Petioles

In the normal apple petiole, the epidermis surmounts a band of collenchyma of two or three compact tiers of cells. Beyond the collenchyma lies a rather broad region of spongy parenchyma the latter bordering on the inside scattered strands of sclerenchyma and phloem. The larger terminating cells of the medullary rays are evident out beyond the phloem.

The diseased region of the petiole is sunken and the surface becomes irregular, dry, and leathery (Fig. 5). In transverse section the epidermal

and collenchyma cells are collapsed. The dead cells are arranged compactly and distorted irregularly. In the spongy parenchyma, the collapse and distortion of the cells is also evident and the cell walls commonly are broken. The necrotic and living tissues of the cortex are definitely separated at a point about midway between the epidermis and the pericycle. The abscission region is sometimes interrupted by strands of sclerenchyma. Here as in the pedicel the protective layer is formed at some distance outside of the sclerenchyma. Underlying the abscission region, in places the cork cambium has given rise to a dense region of parenchyma of small, uniform-sized cells, the phelloderm, arranged in compact, radical layers. In other places the division of the parenchyma cells of the pericycle is evident and appears to account for the presence of strands of sclerenchyma out in the abscission region (Fig. 5). The host is unable to resist the progress of the fungus tangentially and as the result, the epidermis, collenchyma and outer parenchyma may undergo necrosis in this direction until the petiole is girdled. Usually the medullary rays and the vascular elements are influenced by the changes which take place in consequence of which they become somewhat asymmetrically arranged. The same general changes accompany the necrosis of the mid-veins of the leaves (Plate XXXI, fig. C).

LITERATURE CITED

1. CLINTON, G. P. Apple rots in Illinois. Illinois Agric. Exp. Sta. Bull. 69: 189-214. *Pl. A-J*. 1902.
2. LEWIS, D. E. The control of apple blotch. Kansas Agric. Exp. Sta. Bull. 196: 521-574. *21 fig.* 1913.
3. ROBERTS, J. W. The apple blotch and bitter-rot cankers. *Phytopath.* 10: 353-357. 1920.
4. ———. Apple blotch and its control. U. S. Dept. Agric. Bull. 534. *11 p., pl. 1-2, 3 fig.* 1917. Literature cited, p. 11.
5. SCOTT, W. M., and ROBER, J. B. The relation of twig cankers to the *Phyllosticta* apple blotch. *Proc. Benton County Hort. Soc. (Bentonville, Ark.)*. *p. 1-6*. 1907.
6. ———. Apple blotch, a serious disease of southern orchards. U. S. Dept. Agric., Bur. Plant Indust. Bull. 144. *28 p., 6 pl. (1 col.)*. 1909.
7. UNDERWOOD, L. M. Report of the Botanical Division of the Indiana State Biological Survey for 1894. *Proc. Ind. Acad. Sci.* 1894: 144-156. 1895.

DESCRIPTION OF PLATES

PLATE XXX

FIG. A. Photomicrograph of section through a canker from a water sprout showing the marked response of the cambium to the presence of the fungus. The dense protective layer is apparent directly below the strands of sclerenchyma. From material collected December, 1920.

FIG. B. Section through a water sprout showing the arrangement and construction of the normal tissues. From material collected November 20, 1919.

FIG. C. Photomicrograph of section through a canker at the margin showing the wedge-shaped crack directly outside of the periderm. The cork cambium and phelloderm are very much in evidence. From material collected December, 1920.

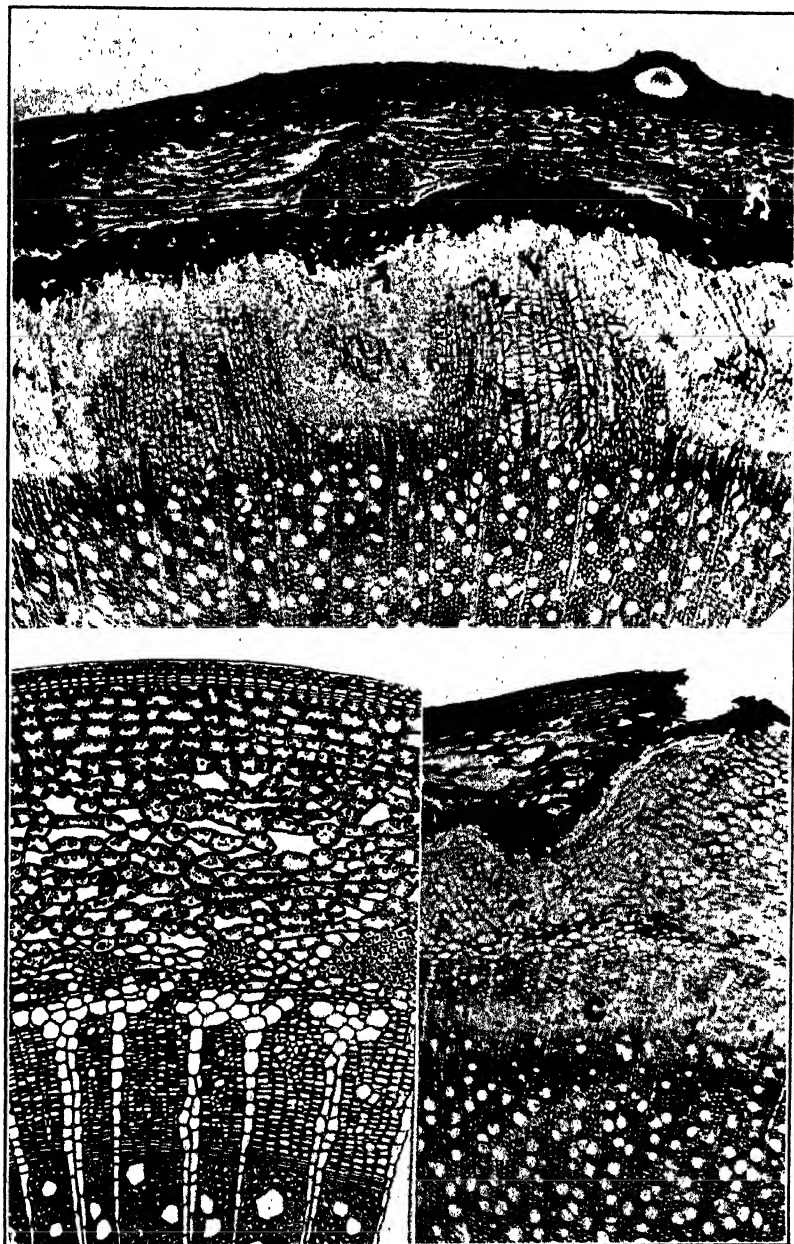
PLATE XXXI

FIG. A. Enlarged view of a portion of an apple leaf affected with *P. solitaria* showing the central position of the usually solitary pycnidium on pale spots of definite sizes and shapes.

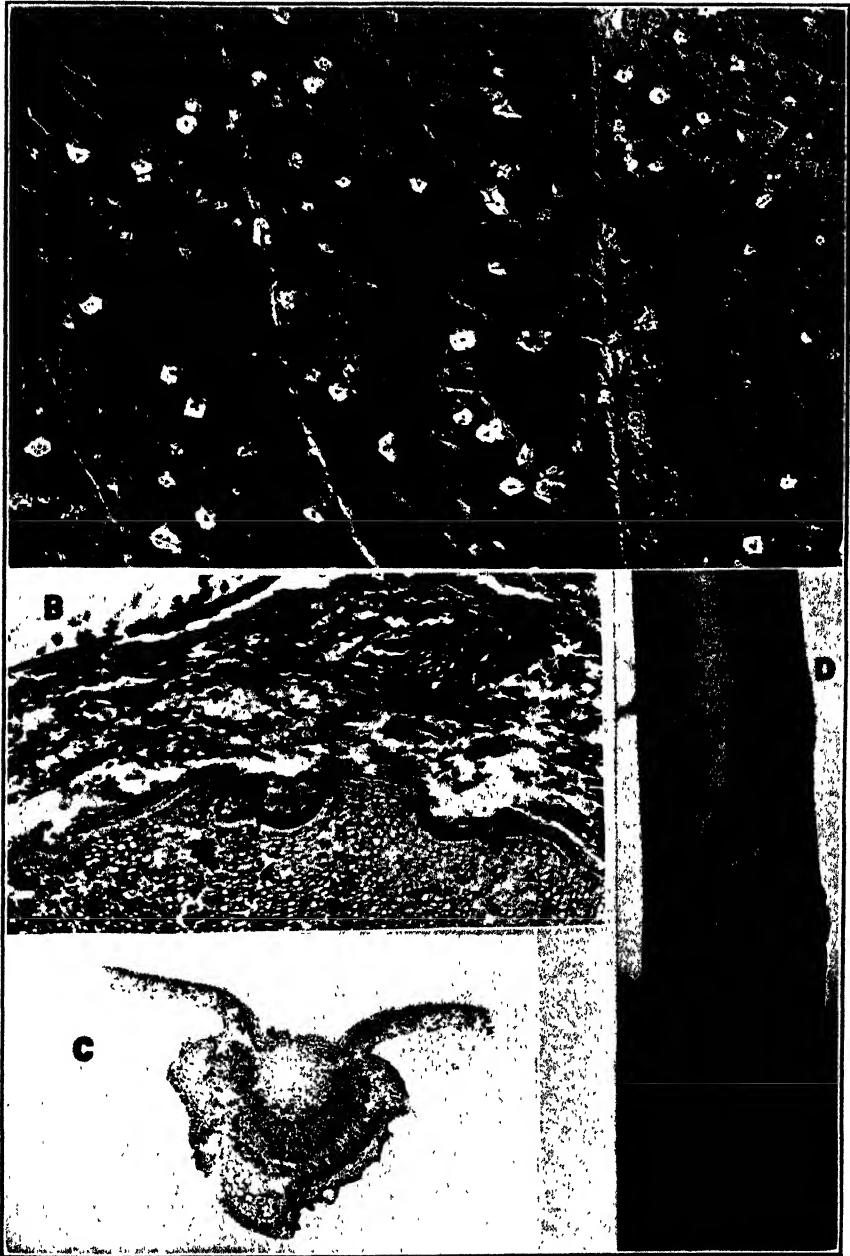
FIG. B. Photomicrograph of a section through a spur canker from a three-year-old twig collected June 2, 1921. The dead cankered area is almost exfoliated and the periderm layer below, formed in the season when infection occurred, has eventually become exposed.

FIG. C. Photomicrograph of a section through an affected mid-vein of an apple leaf showing the sunken irregular surface of the lesion, the abscission layer between healthy and diseased areas, and the compact columnar arrangement of small parenchyma cells beneath.

FIG. D. Apple blotch canker on seven-year-old branch of a Duchess apple tree. Exfoliation of the canker is almost complete yet the fungus still persists in the margin.



PATHOLOGIC HISTOLOGY OF APPLE BLOTCH



PATHOLOGIC HISTOLOGY OF APPLE BLOTCH

CONTROLLING ONION SMUT WITH KALIMAT

P. J. ANDERSON

The use of formaldehyde in controlling onion smut is attended by the danger of killing, or preventing the germination of, the onion seeds. There is a certain amount of loss from this source every season, and under certain moisture conditions of the soil (described in a previous publication¹) it becomes serious.

Such injury may be largely overcome by changing the rate of dilution and application of the formaldehyde according to the moisture condition of the soil.² Control operations would be much simplified, however, if some chemical could be found which could be substituted for formaldehyde and which would give equally good control without the disadvantage of having to change formulas according to the weather or risking a loss of stand. Three years ago the writer began a search for such a substitute and has experimented with a large number of chemicals, some of which have some merit, but, with one exception, none gave a percentage of control equal to the formaldehyde solution. Kalimat,³ the one exception, however, in experiments during the last two years has given just as good control as formaldehyde used according to the same formula and has caused little or no injury even where formaldehyde caused serious loss.

In the present article only the experiments in which these two chemicals were compared are described. Experiments with other substances are still in progress and will be described in a future publication.

PRELIMINARY GREENHOUSE EXPERIMENTS

When a sample of kalimat was first received, rows of seed planted in two small flats of smut-infested soil in the greenhouse were treated with the chemical diluted according to the formulas of 1-50-3000 (=1 pint chemical in 50 pints of water on 3000 feet of row), and 1-100-3000. This initial test, applied to each chemical under experimentation, was merely for the

¹ Anderson, P. J. The relation of soil moisture to formaldehyde injury of onion seedlings. *Phytopath.* 13: 392-403. 2 fig. 1923.

² See Mass. Agr. Col. Ext. Leaflet 79, "How to prevent onion smut." 1924.

³ Kalimat is a formaldehyde preparation recently patented in Germany and used in that country for control of smuts of cereals. It is now marketed in this country by the Chicago Process Co., 2602-2620 North Western Avenue, Chicago, Illinois. It contains other substances besides formaldehyde and it is claimed by the manufacturers that it not only does not impair germination of the seed but that it actually increases the percentage of germination.

purpose of seeing whether it gave indication of fungicidal value warranting further tests. The seed was not counted but an untreated check row was planted in each flat. Both formulas gave good control since only a few of the plants in the treated rows were smutted while practically all the check plants were diseased.

In the next experiment, additional formulas were tried in comparison with the same formulas of formaldehyde. Eighteen rows, each four feet long and containing two hundred seeds, were planted in a greenhouse bench. The soil had been brought from a badly infested field and had a moisture content of 20 per cent when the seed was planted. It was observed when the seedlings first appeared above ground that both the formaldehyde and the kalimat caused a germination delay of 24–48 hours. This was also observed in later experiments and has been observed in all of our formaldehyde treatments. It is probably of no serious import. A few days later, even before smut appeared, damping-off began in the untreated rows but was almost absent from the rows treated with either chemical. For many years it had been observed in the experiments that this damping-off commonly accompanies or precedes the smut and that both diseases are controlled by the same fungicides. Smutted plants are more susceptible to damping-off but the latter disease seems to be always associated with other fungi such as *Pythium*, *Rhizoctonia* and *Fusarium*. The plants which died from damping-off or smut were removed and counted as they dropped. At the end of eight weeks the value of each treatment was determined by counting the number of healthy plants which were still standing. This seems to be the most accurate method of recording the benefits of any treatment for smut because it expresses most directly the amount of benefit which the grower may expect. Counting the smutted plants in an early stage is not accurate because many smutted seedlings recover and make good onions and also because it is frequently impossible to determine, when a plant dies, whether it was killed by smut or by damping-off. The formulas of treatment and results of this experiment are presented in table 1. The results showed that: (1) There was no injury to the seeds by kalimat in any formula; (2) There was apparently a slight injury from formaldehyde when the concentrated formulas of 1–50–3000 and 1–50–4000 were used. None of the other formulas caused any injury but since this soil contained 20 per cent of moisture when the seed was planted, no considerable injury was anticipated.. (3) Kalimat controlled smut just as well as formaldehyde in all dilutions.

Since it had thus been demonstrated that kalimat controlled smut just as well as formaldehyde in a fairly moist soil, the next step was to see what the effect would be in drier soils. In order to keep the soil moisture con-

stant in these tests, pots of galvanized iron, 12 inches in diameter, were filled with infested soil and then brought up to the desired weight every day by adding water. The soil had a water holding capacity of 64 per cent of

TABLE 1.—*Results from use of kalimat as compared with formaldehyde. Greenhouse test in soil of 20 per cent moisture content*

Chemical	Formula	Total germination	Healthy plants left after 8 weeks
Kalimat	1-50-3000	167	121
Formaldehyde	1-50-3000	150	108
Check		164	12
Kalimat	1-50-4000	165	109
Formaldehyde	1-50-4000	141	79
Check		160	5
Kalimat	1-50-5000	170	103
Formaldehyde	1-50-5000	165	110
Check		165	9
Kalimat	1-100-3000	170	109
Formaldehyde	1-100-3000	172	119
Check		166	3
Kalimat	1-100-4000	164	114
Formaldehyde	1-100-4000	170	96
Check		161	3
Kalimat	1-100-5000	156	83
Formaldehyde	1-100-5000	161	65
Check		164	0

the dry weight. One hundred seeds were planted in each of 15 pots. Three pots were kept at 10 per cent moisture, three at 12, 14, 16 and 18 per cent, respectively. One of each group of three was treated with formaldehyde of the formula 1-50-3000, one with kalimat of the same formula and the third was left without treatment. Only a few seedlings came up in the pots of 10 per cent moisture. It was therefore apparent that this soil was too dry for good germination and these pots were discarded. Smutted and damped-off plants were counted and removed as they died just as in the preceding experiment and at the end of eight weeks the healthy plants still standing were counted. The results are presented in table 2.

Both kalimat and formaldehyde gave perfect control in this test since no plant in any treated pot died from smut. On the other hand, the percentage of infection in the untreated pots was almost total. The differences

in the number of plants at the end of eight weeks are, therefore, an expression of the amount of chemical injury and are not affected by any smut loss. The injury from formaldehyde increased with the dryness of the soil as was anticipated in view of our previous results (Phytopath. 13 : 402). Kalimat, on the other hand, caused no decrease in germination, the percentage of seedlings being as high or higher than for the untreated check (except for the 18 per cent moisture where there was an abnormally high germination in the check).

TABLE 2.—*Results of treating the seeds with formaldehyde and kalimat in soils of different moisture content*

Moisture Percentage	Chemical	Number of seedlings which came up	Healthy plants at end of 8 weeks
12%	Kalimat	45	45
	Formaldehyde	24	24
	Check	25	3
14%	Kalimat	54	54
	Formaldehyde	27	27
	Check	56	3
16%	Kalimat	74	74
	Formaldehyde	42	39
	Check	50	1
18%	Kalimat	68	66
	Formaldehyde	65	65
	Check	91	0

These results indicate that in a dry soil the chemical injury is largely eliminated when kalimat is substituted for formaldehyde.

FIELD EXPERIMENTS

Kalimat was used in a small way in our field tests of 1923 on four rows and more extensively in 1924. In 1923 the soil was very dry and the weather remained dry and windy for three days after planting. These conditions caused the most serious injury from formaldehyde which has occurred in any of the experiments during six years. Every formula of application caused some injury while the most concentrated formula, 1-50-3000, ruined the crop where it was applied. At the end of the season these latter rows did not have even as many sound onions to harvest as the untreated rows. Two rows, each seventy feet long, were treated with kalimat

1-50-3000 and two similar rows with kalimat 1-100-3000. When the seedlings came up there was evidence of some chemical injury from the 1-50-3000 formula but none from the more dilute formula. Just before harvesting, the only rows in the whole field which seemed to have a normal number of onions were those treated with kalimat. The results are presented in table 3.

TABLE 3.—*Field experiment of 1923*

Chemical	Formula	Number of rows	Average number good onions harvested per row
Kalimat	1-50-3000	2	180
Formaldehyde	1-50-3000	4	70
Kalimat	1-100-3000	2	280
Formaldehyde	1-100-3000	4	112
Check		4	102

TABLE 4.—*Comparison of kalimat and formaldehyde in the field tests of 1924. Each row 70 feet long*

Chemical	Formula	Number of rows treated	Average number of seedlings per row which came up	Average sound onions harvested per row
Check		12	539	122
Kalimat	1-50-5000	8	544	340
Formaldehyde	1-50-5000	8	538	309
Kalimat	1-50-4000	8	625	432
Formaldehyde	1-50-4000	8	525	331
Kalimat	1-50-3000	4	516	380
Formaldehyde	1-50-3000	4	469	285
Kalimat	1-100-3000	4	593	331
Formaldehyde	1-100-3000	4	416	293

In 1924, kalimat was tested more extensively and each treatment duplicated on four to eight rows in different parts of the field. Alongside each two rows treated with kalimat were two rows treated with formaldehyde of the same formula. Planting was purposely delayed until a time when the soil was very dry in order to test the kalimat on a dry soil, but rains

began within a few hours after planting, with the result that the injury from formaldehyde was not very serious. Nevertheless, an inspection of table 4 shows that there was considerable loss from the more concentrated formaldehyde formulas while there was no loss in any case with the kalimat except for a possible slight one with the 1-50-3000 formula. If one uses the number of onions harvested at the close of the season as the basis of comparison, the results in every case are strikingly in favor of kalimat. The best results were obtained with the 1-50-4000 formula.

CONCLUSION

In all tests during the last two years, kalimat has controlled onion smut just as well as formaldehyde. It is superior to formaldehyde however not on account of its fungicidal properties but on account of its comparative safety when used in concentrated solutions or when used in very dry soils. Under these same conditions formaldehyde frequently causes serious injury.

The claim of the manufacturers that the percentage of germination is increased by the use of kalimat would seem at first to have some support in the data presented in tables 1, 2 and 4. Of the 14 comparisons between treated and check rows tabulated there, 10 show that there were more seedlings on the treated than on the untreated rows. This does not necessarily mean however that kalimat stimulated germination of the seeds; it may have merely killed off some organisms which naturally destroy the seedlings before they reach the surface of the soil.

The only objection to the use of kalimat is that it is rather expensive at present. It may be obtained for about \$1.00 per pint. In larger quantities however it could probably be obtained at a lower price. If any considerable demand for it should be developed, the cost of production will be lowered or other substances embodying the same protective principle will appear on the market.

Of the formulas tried, probably the 1-50-4000 could be recommended as giving excellent control and as being economical of labor and material. This would require about five quarts of kalimat per acre of onions when the rows are thirteen inches apart. In extremely dry soil the same amount applied in greater dilution might have some advantage.

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CELLULAR INTERACTION BETWEEN HOST AND PARASITE

CLIFFORD H. FARR

WITH TWELVE FIGURES IN THE TEXT

In the study of the normal development of higher organisms, important consideration is recently being given to the effects of one cell upon another. These effects may be in the nature of stresses and strains brought about by one cell exerting pressure or tension upon a neighboring cell, or they may be chemical effects. In such studies one method of attack is in exposing cells to certain external mechanical or chemical stimuli and observing the alteration made by the cell. Another method is to investigate the effects of one organism upon another in close association with it. A number of investigators have been working recently upon the pressure exerted by a fungus hypha in pushing through the cell wall of its host. It occurred to the writer that further light might be thrown upon this question of cellular interaction, if root-hairs of susceptible and resistant host plants were grown with fungus hyphae under microscopic observation.

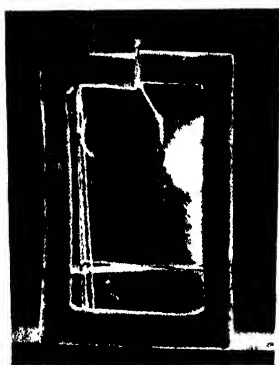


FIG. 1. Mount ready for microscope, containing tomato seedling and wilt fungus.



FIG. 2. Hyphae of wilt fungus sending out numerous branches to root-hairs of Stone tomato.

For this purpose cultures of *Fusarium lycopersici* were furnished through the courtesy of Dr. Fred J. Pritchard, of the Bureau of Plant Industry. They were grown on agar in damp chamber mounts, which I¹ have described recently, and into these mounts were inserted seedlings of tomato.

¹ Farr, C. H. A damp chamber for microscopes. *Science* 56: 227-228. 1922.

(Fig. 1.) The resistant varieties of tomatoes used were Marvel, Columbia, and Norton, described by Pritchard,² and Stone was used as a susceptible variety, which Pritchard reports as becoming 96.1 per cent infected, and which Edgerton and Moreland³ state is extremely susceptible. While the tomato wilt fungus has not been found to penetrate the root hairs of the tomato, yet Tisdale⁴ has shown that *Fusarium lini* does penetrate the root-hairs of both susceptible and resistant varieties of flax, and that the same is true of *Fusarium conglutinans* on cabbage.⁵ The difference between re-

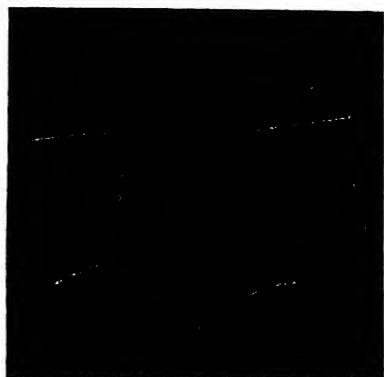


FIG. 3. Branches of hyphae extending along opposite sides of a root-hair.

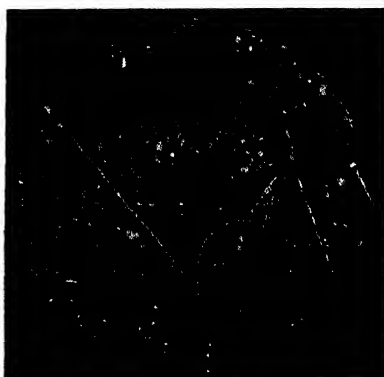


FIG. 4. Hyphae sending out branches toward root-hair at some distance.

sistant and susceptible varieties in these cases seemed to be that the former develop a corky tissue after infection, walling off the parasite. Although penetration of the tomato wilt fungus apparently does not occur through the root-hairs, and although in this case also both resistant and susceptible varieties are infected, yet it is possible that some difference in reaction between the host and parasite may be discovered. The accompanying photomicrographs show the results of the experiments performed. Figures 2 to 6, inclusive, present root-hairs of the Stone variety of tomatoes being attacked by hyphae of the tomato wilt fungus. Although careful search was made of numerous instances like these in which the hyphae were closely

² Pritchard, F. J. Development of wilt-resistant tomatoes. U. S. Dept. of Agriculture Bull. 1015. 18 p., 10 pl. 1922.

³ Edgerton, C. W., and Moreland, C. C. Tomato wilt. Louisiana Agric. Exp. Sta. Bull. 174. 54 p., 19 fig. 1922.

⁴ Tisdale, W. H. Flax wilt: A study of the nature and inheritance of wilt resistance. Jour. Agric. Res. 11: 573-605. 1917.

⁵ Jones, L. R., J. C. Walker and W. B. Tisdale. Fusarium resistant cabbage. Wisc. Agric. Exp. Sta. Res. Bull. 48. 34 p., 10 fig. 1920.

appressed to the root-hair, no instance was seen in which there seemed conclusive evidence that the hyphae had penetrated into a living root-hair. A few instances of hyphae branching in the vicinity of root-hairs might be regarded as coincidence. But the many instances observed, and such instances of obvious reaction on the part of the hyphae as is seen with both hyphae in figure 2, make it seem certain that the branching of the hypha is in direct response to a stimulus received in some way from the root-hair. In some instances, as in figures 2, 3 and 4, the hyphae and root-hairs are in the film of water on the coverglass of the mount. In such instances the stimulus may be transported in the aqueous solution. In other cases,



FIG. 5. Near center may be seen the close association of hyphae about root-hair.



FIG. 6. Hyphae branching toward hairs.

however, as in figures 5 and 6, both hyphae and root-hairs are in mid air in the damp chamber. The stimulus must in these cases operate through the atmosphere. The response of the fungus is in the nature of a morphotic movement. No tropic or nastic movements of the hyphae were detected. The first evidence of a response is the sending out of branches in the direction of the root-hair.

Cultures were made of the Marvel, Columbia, and Norton varieties of tomatoes resistant to wilt. In no instance were the morphotic reactions described above seen in these. Figure 7 shows two hyphae crossing two root-hairs, without giving any response. Figures 8, 9, and 10 are of the same hypha and root-hair taken at fifteen minute intervals, showing the rate at which the hypha and root-hair elongate. It is evident from these pictures that the hypha grows several times faster than the root-hair.

An occasional root was found which showed a marked response to the presence of the fungus. In all cases these were roots of Stone seedlings.

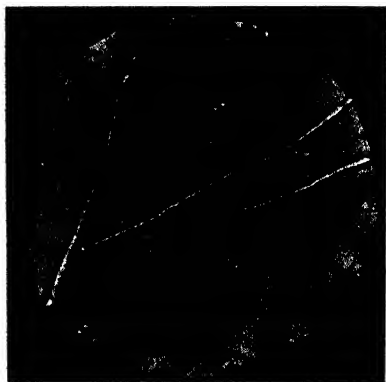


FIG. 7. Hyphae of tomato wilt fungus crossing root-hairs of Marvel.



FIG. 8. Hypha of *Fusarium lycopersici* just crossing root-hair of Marvel at 11:45 p. m.

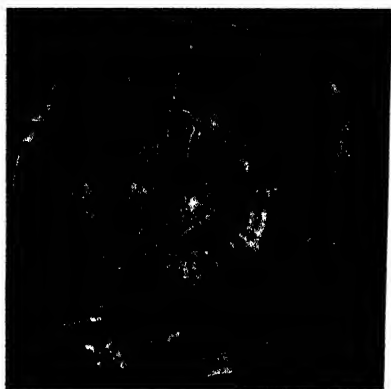


FIG. 9. Another view of same hypha and root-hair as in fig. 8, at midnight.



FIG. 10. Another view of same hypha and root-hair as in fig. 9, at 12:15 a. m.

Figure 11 shows such a root, with no root-hairs on the lower portion of the region of absorption on the side from which the root-hairs are approaching, while normal root-hairs have developed on the other side. At the time this formation had begun long before the hypha came in contact with the root but in a different plane of focus, and hence do not show in this picture. It is evident, however, that the reaction of the root in inhibiting root-hair formation had begun long before the hyphae came in contact with the root or any of the root-hairs. It would seem then that the stimulus is trans-

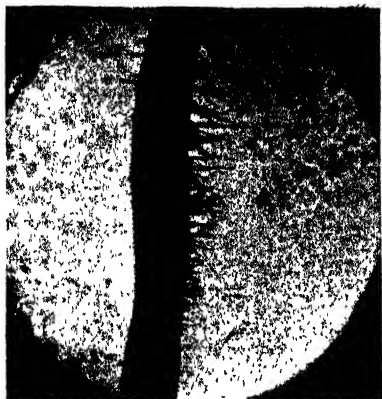


FIG. 11. Root of Stone being approached by hyphae from the left. Note absence of root-hairs on that side.

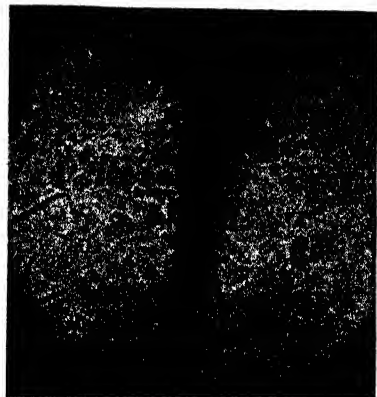


FIG. 12. A root of Marvel, showing normal development of root-hairs even in the presence of the wilt fungus.

ferred from the fungus to the root through the atmosphere of the damp chamber. Miss Snow⁶ and others have shown the inhibiting effect of lack of oxygen upon the production of root-hairs. This is a possible explanation here, though it is difficult to understand how the concentration could be enough different on the two sides of the root to account for the result. Roots of Marvel did not show this response to the fungus, as is seen in figure 12. It is thus shown that the susceptible varieties of host show a morphotic reaction to the parasite, while the parasite also shows a morphotic reaction toward the susceptible host.

⁶ Snow, L. M. The development of root hairs. *Bot. Gaz.* 40: 12-48. *pl. 1, fig. 10-15.* 1905.

MEASURING WATER FLOW INTERFERENCE IN CERTAIN GALL AND VASCULAR DISEASES

I. E. MELHUS, J. H. MUNCIE AND WM. T. H. HO

WITH ONE FIGURE IN THE TEXT

The nature and extent of the injury caused by gall and wilt diseases are not well defined. The symptoms associated with these types of diseases suggest as one of the causes, some disturbance of, or interference with the sap flow in the vascular system. This relationship of galls to sap flow interference was first studied in crown gall (*Bacterium tumefaciens*) on young apple trees and tomato plants. Again this phenomenon of water flow and wilting incident to the wilt diseases was studied in cabbage yellows (*Fusarium conglutinans*), and an alfalfa wilt (causal agent unknown). The flow interference in plants affected with the diseases enumerated, was measured, using a special piece of apparatus designated a fluometer. In addition to detecting the presence or absence of water flow interference, this apparatus reveals the degree of functioning of the ducts and their actual distribution when water soluble stains are employed. A description of the apparatus and some of the data obtained are presented.

The apparatus, as illustrated in the accompanying figure, consists essentially of a filter pump (7) which exhausts the air from the system. A filtering flask (4) is used as a trap to prevent water from backing into the tubes when the pump is shut off without releasing the suction. A mercury column (1), the base of which extends into a volume of mercury in a filtering flask is coupled to the system. By controlling the height of this column, a constant pressure can be maintained. A side delivery burette (8) gauges the amount of water flow through the stem and a separatory funnel (5) serves as a reservoir for water that can be admitted into the burette (8), after the stem is attached and before suction is applied.

The manipulation is very simple. Clamp number 2 is closed and the pump is started; this lowers the mercury column to the desired pressure in about two minutes with average water pressure on the pump. A section of plant stem (6) of standardized length, is then attached to the end of the burette (8) by a short piece of rubber tubing and immersed in water in the jar (9). Water is then admitted from the reservoir (5) to bring the level up to any desired graduation on the burette. Clamp (10) is tightly closed, then clamp (3) is closed and finally clamp (2) is opened. Suction then begins on the stem. When clamp (2) is opened the mercury momentarily rises but returns to its former lower level when equilibrium is established.

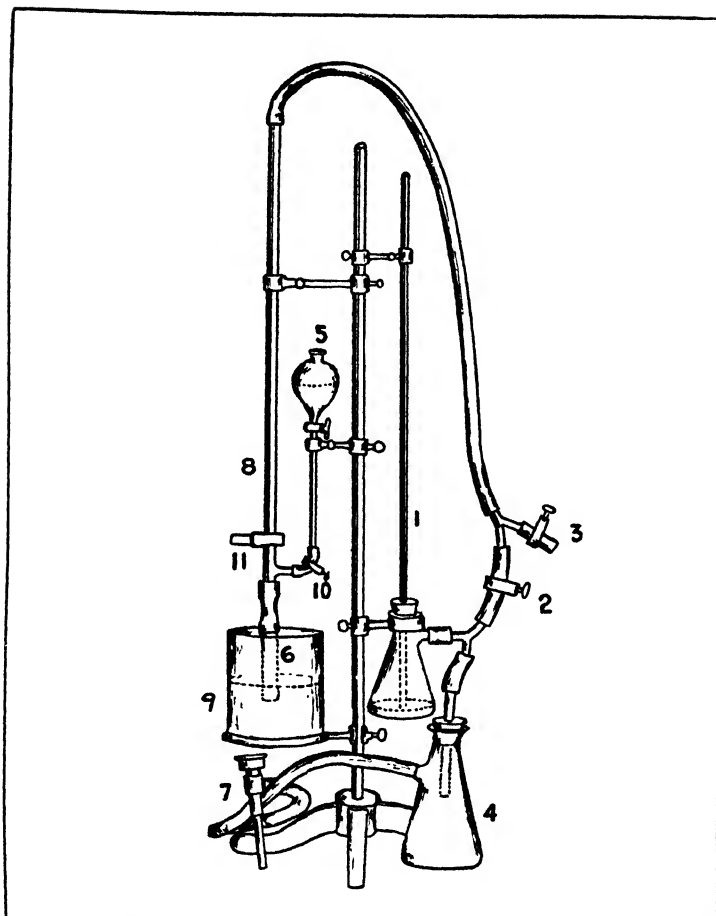


FIG. 1. Fluometer.—1. Mercury column showing reduced pressure obtained by the filter pump (7).—2. Clamp for maintaining vacuum in the mercury flask. By closing this clamp the suction on the system is held while a new specimen is inserted in the rubber connection on the end of the burette (8).—3. Clamp for releasing the vacuum on the burette while changing specimens.—4. Filter flask which serves to prevent back-water from entering the system after the filter pump is shut off.—5. Separatory funnel reservoir. Water is admitted from this funnel into the burette (8) to any desired graduation before suction is applied.—6. The specimen attached by a rubber tubing connection to the burette (8).—7. Filter pump by means of which vacuum is produced in the system.—8. Graduated burette into which the water is pulled through the specimen.—9. Jar of water into which the end of the specimen is placed.—10. Clamp for closing the connection between the reservoir (5) and the burette (8).—11. Meniscus reader marking the water level in the burette (8) before suction is applied. This facilitates reading the water flow through the specimen.

After suction begins, bubbles frequently rise from the stem into the burette; these, however, are soon exhausted and the water in the burette slowly rises as its volume is increased by intake through ducts in the stem. The rate of this flow can then be timed. A meniscus reader (11) marking the height of the water column before suction is applied, facilitates recording the volume per minute passing into burette.

After the flow has been observed, clamp (2) is closed in order to maintain suction on the mercury column, and clamp (3) is opened to release the vacuum in the rest of the system. A new piece of stem can then be attached to the burette end and the process repeated. By keeping clamp (2) closed when attaching a new stem to the burette, the vacuum in the mercury flask is maintained thus saving several minutes on each trial that would otherwise be spent in lowering the column.

By the use of the above described apparatus, the rate of water flow in 100 galled and 100 healthy apple trees was determined. The trees used in these tests were two year "cut backs." A section of each tree was selected 15 cm. long including the union and a part of the scion and stock. All lateral roots were cut off close to the stock. The reading on the burette at the end of the second five minute period was taken as the rate of flow.

In the following table are given the mean rates of flow through the sections of galled and healthy apples. It will be noted that there is a difference in the rate of flow through galled and healthy trees. The average reduction in the rate of flow in the trees cited in the above table is 30 per cent. It should be noted that there is considerable variation in rate of flow in the galled trees. This is probably an indication of the extent of interference by the gall in the infected tree.

TABLE 1.—*Mean rate of flow in galled and healthy apple trees*

Diameter of piece	Galled trees Rate of flow in 5 minutes	Healthy trees Rate of flow in 5 minutes
1.6 cm.	2.7 cc.	4.3 cc.
1.7	5.1	6.9
1.8	4.6	7.8
1.9	7.4	8.2
2.0	5.0	9.2
Weighted mean	5.3 cc.	7.4 cc.

This apparatus is readily adapted to the detection of interference or stoppage of the water flow in herbaceous as well as woody plants. This is shown in the results on cabbage plants affected with cabbage yellows, (*Fusarium conglutinans*). The symptoms associated with this disease

seem to be due to the partial or complete stoppage of the vascular system. Those plants that show only a partial stoppage, die slowly, while those showing no flow succumb quickly. In the following table, representative data are presented.

TABLE 2.—*Rate of flow through healthy and yellows affected cabbage stems*

Diseased		Healthy	
Diameter of stems	Rate of flow in five minutes	Diameter of stems	Rate of flow in five minutes
14 mm.	1.7 cc.	14 mm.	17.2 cc.
15	0.5	15	10.0
15	2.0	15	11.4
15	2.0	15	15.0
15	2.3	16	7.2
16	0.6	16	17.2
16	1.0	16	23.0
16	1.0	16	24.5
16	4.5	16	25.0
17	3.0	17	9.0
Average 15.5 mm.	1.86 cc.	15.6 mm.	16.02 cc.

From the above table we observe that the mean flow of 10 healthy cabbage stems, with an average diameter of 15.6 mm. is 16.02 c.c. in 5 minutes, while that of 10 diseased ones, with an average diameter of 15.5 mm. is only 1.86 c.c. for the same length of time.

Not only is this apparatus adapted to studying the rate of flow in stems, but also in fleshy roots. The data obtained in the study of an alfalfa wilt disease now under investigation in our laboratory show a typical response. The vessels of the wilt infected plants are filled with a gummy exudate and micro-organisms which apparently cause a complete plugging of most of the ducts. The comparative response of healthy and wilt affected plants is shown below:

TABLE 3.—*Mean rate of flow in diseased and healthy alfalfa roots*

	Diseased roots	Healthy roots
Circumference of root	Rate of flow per minute	Rate of flow per minute
1.0 cm.	0.85 c.c.	2.75 c.c.
1.1	0.92	2.92
1.2	0.72	3.90
1.3	3.50	4.50
1.6	3.30	9.00
Weighted mean	0.97	3.85

The data presented suggest that the vascular distortion caused by crown gall (*Bacterium tumefaciens*) in the trees studied, induces sufficient interference to reduce the rate of water flow 30 per cent. The wilting incident to field infection of cabbage with *Fusarium conglutinans* is due to a partial or complete stoppage of the ducts in the vascular system. The alfalfa wilt results from a vascular plugging. In this case, a gummy exudate filling the ducts is readily detected in stained sections.

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A METHOD OF INCREASING THE EFFICIENCY OF FILTER CYLINDERS

H. H. MCKINNEY

WITH ONE FIGURE IN THE TEXT

The efficiency of filter cylinders is greatly reduced when any part of the filter is not covered by the fluid being filtered. This is due to the reduction in the amount of filter surface and to the decreased efficiency of the aspirator on account of air leakage through the exposed portion of the filter. The use of mantles of small diameter aids in the reduction of this inefficiency, but this practice makes it necessary for the operator to remain with the apparatus constantly to keep the mantle filled.

In order to eliminate these difficulties, the writer has devised a glass tube, for convenience called "filter tube," which has an inside diameter slightly larger than the outside diameter of the filter to be used. The bottom of this filter tube is open and the top is designed to be closed, as shown in figure 1. The fluid to be filtered is placed in the mantle and the filter tube is placed over the filter, the upper end being left open to allow the air to escape. In case the mantle is not full, the excess air in the filter tube is drawn off through the opening and the top is then closed. Thus the fluid fills the filter tube and covers the filter as long as the bottom opening of the filter tube is under the fluid.

This method is especially advantageous when it is desired to filter fluids containing much colloidal material, since it enables the efficient use of large filters. In the filtration of plant juice containing chlorophyll, the writer uses large 2" x 10", coarse, diatomaceous filters with filter tubes, as shown in figure 1 *a* and *b*. The chlorophyll deposit is removed frequently from the surface of the filter and the resulting clear filtrate is later passed through fine bacteria-proof filters.

When using small-sized filters, the writer employs filter tubes made of short lengths of ordinary large-sized glass tubing, or test tubes which have their bottoms cut off. The upper end of such a tube is closed with a rubber stopper with single opening. In this is placed a ground-glass stop cock, or a short glass tube carrying a piece of rubber tubing with clamp cock. When using the Livingston atmometer cup as a filter, it usually is necessary to pour agar into the mantle in order to seal all possible openings which may occur around its base, and to raise the bottom of the mantle to the unglazed portion of the cup. When using a filter tube with such a setup, it is necessary to use a hot wax, such as paraffin, for sealing

instead of agar, as agar is too soft and is lifted out of place by the force of the fluid entering the base of the filter tube.

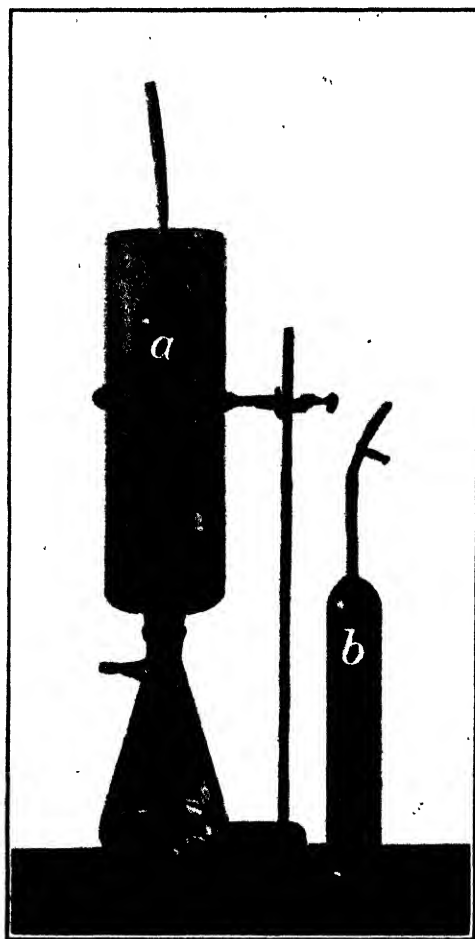


FIG. 1. Large-sized filter with glass-stoppered filter tube in position (a). Large-sized filter tube (b) equipped with plain glass tubing outlet. A short piece of rubber tubing and clamp cock provide an inexpensive sealing device.

OFFICE OF CEREAL INVESTIGATIONS,
BUREAU OF PLANT INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE,
AND UNIVERSITY OF WISCONSIN,
MADISON, WISCONSIN

PHYTOPATHOLOGICAL NOTES

Java Gum Disease of Sugar Cane Identical to Leaf Scald of Australia.

The writers, after a conference in Honolulu in which formalin specimens and photographs have been compared, wish to point out the similarity between the disease of sugar cane known as leaf scald in Australia and the gum disease described by Miss Wilbrink¹ which occurs in both Java and the Philippine Islands. The pallid-white, evenly-edged, leaf streaks, reddened vascular bundles, production of shoots from the nodes and general leaf appearance are apparently identical in both diseases. The work, soon to be published, of the first mentioned of the writers of this note, shows the great similarity between the causal organism of leaf scald in Australia and the organism described as the cause of the Java gum disease by Miss Wilbrink.

The Java gum disease as described by Miss Wilbrink is decidedly different from Cobb's gumming disease of sugar cane and since it may lead to confusion to continue with such a name, it seems desirable to adopt the rather descriptive name leaf scald as used in Australia for this trouble.

Leaf scald of sugar cane has been recorded, to the present time, only in Australia, Fiji, Java and the Philippines. We regard it as one of the most destructive of the diseases of sugar cane, and sugar countries of the western hemisphere should exert every possible effort to prevent its introduction.—D. S. NORTH, II. ATIERTON LEE.

Personals: There died suddenly, on August 20, on the occasion of an excursion of the Hamburg Horticultural Society, Prof. Dr. Carl Brick, the Director of the Station für Pflanzenschutz, Hamburg, Germany. Brick was born in 1863 at Stolp, in Pomerania, and studied Natural Sciences at the University of Breslau. In 1888 he secured his Ph.D. on "Contributions to the biology and comparative anatomy of Baltic shore plants." He then went to the Botanical Museum, Hamburg, and later became first assistant at Karlsruhe, where he lectured on Forest Botany and Soil Science. He returned in 1891 to the Hamburg Museum, and in 1898 became director of the new Pflanzenschutzstation, where he successfully worked until his end. Among his many contributions to science there may be mentioned his studies of the parasitic fungi and insects of imported fruit, the fungus flora of the Sachsenwald and diseases of tropical plants.—H. T. G.

¹ Wilbrink, G. De gomziekte van het suikerriet, hare oorzaak en hare bestrijding. Mededeelingen van het Proefstation voor de Java-Suikerindustrie. XXVIII, 2 deel, 1921, p. 1399.

An unusual infection of Polyporus Schweinitzii Fr.—This fungus on living trees is a typical root and butt rot, usually confined to the heartwood of the first ten feet of the trunk although it occasionally extends considerably higher. In all such cases observed, however, the rot column has been continuous from the butt of the tree upward and the infection court always seemed to be in the roots or in old scars just above the ground level.

It was with considerable surprise that at Alder, Pierce Co., Washington, on July 7, 1922, a living Douglas fir (*Pseudotsuga taxifolia* (Lam.) Br.) with a diameter at breast height, outside the bark, of 60 inches was found with a cluster of *Polyporus schweinitzii* sporophores issuing from an old knot at 51 feet above ground level. The tree had been felled on a logging operation, leaving a stump 4 feet high, and then two logs had been cut out, each 32 feet long. The sporophores occurred 15 feet from the base of the second log but there was no decay in either the base or top of the log. Likewise the stump and first log were free from decay. Obviously the decay was the result of a local infection, probably through the old knot from which the sporophores issued.—J. S. BOYCE.

The November number of Phytopathology was issued December 2, 1924.

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